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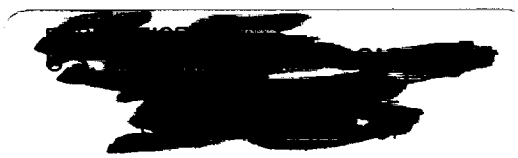

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(NASA CR-52665)

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Proceedings of the

Mercury-Atlas Booster Reliability Workshop

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XEROX $ 19.75 pl
MICROFILM $ 10.13 mf
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Workshop sponsored by Space Systems Division of the Air Force Systems Command and General Dynamics/Astronautics, A Division of General Dynamics Corporation, with the cooperation of the National Aeronautics and Space Administration.

TITLE

Proceedings of the

Mercury-Atlas Booster Reliability Workshop

[HELD AT]

Town and Country Hotel
500 West Hotel Circle
San Diego, California

12 July 1963

Note

The following proceedings of the Mercury-Atlas Booster Reliability Workshop were taken in stenotype shorthand and transcribed.

Agenda

9:00 to 9:10 a.m.	Welcome and Introduction — Mr. Bruce McKay
9:10 to 10:30 a.m.	Keynote Addresses U. S. Air Force — Maj. Gen. B. I. Funk, represented by Col. Robert Hoffman National Aeronautics & Space Administration — Mr. Walter Williams General Dynamics|Astronautics — Mr. J. R. Dempsey
10:30 to 10:45 a.m.	Coffee Break
10:45 to 12:00 noon	Management Panels Management Review — Col. R. Hoffman, Chairman Human Factors — Lt. Col. R. H. Brundin, Chairman Supplier Coordination — Col. F. E. Brandeberry, Chairman
12:00 to 1:30 p.m.	Buffet Lunch
1:30 to 3:45 p.m.	Design Control Panel — Mr. J. Bailey, NASA Manufacturing and Process Control Panel — Col. M. K. Andresen Test Control Panel — Mr. G. M. Preston
3:45 to 4:00 p.m.	Coffee Break
4:00 to 4:50 p.m.	Summary of Panel Findings — Respective Chairmen
4:50 to 5:00 p.m.	Closing Remarks — Mr. J. R. Dempsey
5:00 to 6:00 p.m.	Social Hour

Subject Management Review

Time 10:45 to 12:00 noon

Location Atlas Room

This panel will review management of the Mercury-Atlas booster program, dealing with such factors as: the importance of a detailed program plan; recognition of management tradeoffs in the areas of reliability, cost, and schedules; organization for project management; program audit; and corrective action.
Panel members are:

Col. Robert Hoffman, USAF, Chairman
Mr. C. S. Ames, Astronautics, Coordinator
Mr. P. I. Harr, Astronautics, Coordinator
Mr. C. T. Newton, Astronautics, Coordinator
Mr. J. R. Dempsey, Astronautics
Maj. C. L. Gandy, USAF
Mr. B. Hohmann, Aerospace
Mr. J. McNamara, Rocketdyne
Mr. A. S. Torgeson, McDonnell
Mr. W. Williams, NASA

Subject Human Factors

Time 10:45 to 12:00 noon

Location Towne and Esquire Room

This panel, in discussing human factors, will focus on motivation of personnel in the program. Specifically considered will be areas such as reliability, subcontractor programs, visual devices, training philosophy, and Air Force and NASA coordination. Panel members are:

Lt. Col. R. H. Brundin, USAF, Chairman
Mr. R. Evans, Astronautics, Coordinator
Mr. J. Croft, Astronautics
Mr. V. Heger, Astronautics
Mr. F. Johnson, AiResearch
Mr. R. Keehn, Astronautics
Dr. D. Meister, Astronautics
Lt. Col. P. W. Richardson, USAF
Mr. R. Rovenger, NASA

Subject Supplier Coordination

Time 10:45 to 12:00 noon

Location Sunset Room

This panel will examine three aspects of supplier coordination: vendor evaluation and selection, purchase order control, and vendor corrective action. Panel members are:

Col. F. E. Brandeberry, USAF, Chairman
Mr. J. H. Johnson, Astronautics, Coordinator
Mr. S. Braun, Astronautics
Mr. J. W. Cook, Kearfott
Mr. C. Hargiss, Rocketdyne
Mr. L. I. Medlock, Astronautics
Mr. D. E. Moore, USAF

Subject Design Controls

Time 1:30 to 3:45 p.m.

Location Atlas Room

The design control panel will discuss Mercury-Atlas booster design techniques and review, product review, Air Force design surveillance, ASIS design techniques, and Aerospace Corp. surveillance. Panel members are:

Mr. J. Bailey, NASA, Chairman
Mr. M. Rosenbaum, Astronautics, Coordinator
Mr. P. E. Culbertson, Astronautics
Maj. C. L. Gandy, USAF
Mr. R. I. Kreisler, Astronautics
Mr. E. R. Letsch, Aerospace
Mr. H. L. Newman, Astronautics
Mr. J. W. Schaelchlin, Astronautics

MR. WITHEE:

Good afternoon, gentlemen.

It is my privilege this afternoon to invite you to this session on Test Control on the Mercury-Atlas Booster Reliability Workshop.

It is also my privilege and honor to introduce your chairman to you at this time. I don't think many of you need an introduction to him, particularly if you were in the morning sessions. You saw him on the film rushing through the crowd for the president to hand him his award. Normally he is on time, I guess nobody told him that he was going to get that award.

However, briefly, our chairman for this session has been with NASA for twenty-four years and during this period has worked at the Lewis Research Center and the Langley Research Center.

He went on the Mercury program in 1958 and is presently manager of AMR operations for the Manned Spacecraft Center at Houston.

I think his experience and background certainly qualify him very highly for his job today as chairman and monitor of this session.

With that I will turn the meeting over to Mr. G. Merritt Preston.

MR. PRESTON:

Thank you, Wally.

I would like to philosophize a few minutes here before we start with the main program.

You have heard a lot of discussion today about the teamwork of this project in Mercury and I think the reason for the repetition of this statement was because it truly was a terrific teamwork effort. But I think you have to realize what teamwork really is and I feel that there are probably two vital things that create teamwork and the first one, of course, is the management that will delegate authority and responsibility and assign it in such a manner that the people know what their jobs are and once they have assigned this job, that other people try to help other people do their work, but trying not to invade on their job of doing their own work.

So this ends up with a mutual respect for the individuals involved in the program and I think much of the success of Mercury was dependent on the fact that NASA respected the Air Force, Convair and their abilities to provide us with a booster that would perform the task and as such we did not try to supervise them or monitor them in extreme detail.

We were interested in the major problems and they willingly told us about the major problems.

So I think that teamwork is dependent on delegating authority and letting a man do his job after you have delegated it.

The second item I would like to discuss a little bit is about what testing is and how you do the testing.

I have been in testing for twenty-four years. In fact, my whole professional career has been spent in testing and one of the most important things to develop in testing, I think, is what I call technical honesty. It is pretty easy when you are conducting a test to disregard test points because these oddball test points only mean trouble. They only mean work on your part and you have to explain why they are odd and usually the general tendency is to say that the data is no good because you can't understand them.

Well, the truth of the matter is usually because you haven't been able to explain what the trouble is. It is not that the data is no good.

I think to obtain the reliability that is necessary, you have to pay very particular attention to these data points that don't look good because they are the ones that are really important. The ones that are normal are the ones that look good, they are that way because you expect them to be that way.

Any tendency to disregard data and declare it is bad data is probably the first step to unreliability.

How do you obtain a good test engineer?

I think first of all you have to have curious people. They have to be curious to look into all of the results that are being produced, like I said,

Subject Manufacturing and Process Controls

Time 1:30 to 3:45 p.m.

Location Towne and Esquire Room

This panel will examine some of the Mercury-Atlas booster program manufacturing and process controls. These include: contamination, welding, and configuration controls, nondestructive testing, training, motivation, parts selection, test correlation, spares handling, transportation, production plans, and post surveillance and coordination. The panel also will examine the policy on rework, special procedures at composite, product completeness, and how to improve communications. Panel members are:

Col. M. K. Andresen, USAF, Chairman
Mr. E. D. Bryant, Astronautics, Coordinator
Mr. D. Archibald, Astronautics
Mr. G. Grossaint, Astronautics
Maj. I. B. Hanson, USAF
Mr. A. Hinck, USAF
Mr. J. Hopman, Astronautics
Mr. F. B. Kemper, Astronautics
Mr. S. Simkinson, NASA
Mr. L. Tuttle, Astronautics

Subject Test Control

Time 1:30 to 3:45 p.m.

Location Sunset Room

The test control panel will discuss such tests as receiving and inspection, qualification and demonstration, and factory vehicle acceptance; flight and Air Force test controls; Aerospace Corp. technical direction; and failure analysis and data control. Panel members are:

Mr. G. M. Preston, NASA, Chairman
Mr. W. J. Maloney, Astronautics, Coordinator
Mr. W. W. Withee, Astronautics, Coordinator
Mr. R. Gilliland, Astronautics
Mr. D. W. Heagy, Astronautics
Mr. R. W. Keehn, Astronautics
Mr. L. I. Medlock, Astronautics
Mr. T. J. O'Malley, Astronautics
Lt. Col. P. W. Richardson, USAF
Mr. J. F. Wambolt, Aerospace

Subject Keynote Addresses

Time 9:10 to 10:30 a.m.

Location Atlas Room

U. S. Air Force — Col. Robert Hoffman
National Aeronautics & Space Administration — Mr. Walter Williams
General Dynamics|Astronautics — Mr. J. R. Dempsey

MR. McKAY:

Good morning. Welcome to the Mercury-Atlas Booster Reliability Workshop.

I am Bruce McKay of General Dynamics/Astronautics.

I would like to spend a few minutes here to start out before we get settled down on the administrative details for the day.....

About this Workshop, this and the final hour of the day will be the only general sessions. The other four hours and thirty minutes will be devoted to audience participation working sessions. These work sessions will be chaired by a member of NASA or the Air Force with panel members from the Air Force, NASA, and industry who have had close association with the Atlas-Mercury program.

The goal today is to make available and to communicate lessons learned and experience gained on the Mercury-Atlas Booster program so that it may be applied to future space programs. Each session will be opened with a three- or four-minute statement from the Chairman and each panel member. After these opening statements, the sessions will be opened for an exchange for all participants. You are part of this Workshop, everybody in this room.

During the last session of the day each Chairman will give a short summary of his Workshop.

It is planned to record and compile a report for your future use and forward it to you. Today we have sixty-five major companies represented and they represent a major portion of the aerospace industry, the Air Force, Navy, aerospace corporations, and representatives of the executive offices.

I would like to point out that this is an unclassified session and it is open to the press.

Introducing our first keynote speaker, Colonel Robert Hoffman, Deputy for the Air Force Space Systems Division.

Colonel Hoffman.

COLONEL HOFFMAN:

Thank you, Bruce.

I would like to read a telegram we received this morning.

"Thank you for your kind invitation to attend the Joint SSD-NASA-General Dynamics Mercury-Atlas Workshop. I regret that my schedule will not permit me to participate in this very worth-while project. Please extend my personal thanks to General Funk and Mr. Dempsey. My best wishes for a successful program." Signed "Eugene M. Zuckert, Secretary of the Air Force."

General Funk has asked me to represent him today at the meeting and it is indeed a pleasure to act as a representative for the Air Force, for I feel it is a distinct honor to stand here in behalf of all those Blue-Suit individuals who have made personal contributions to the success of the Mercury program.

It is also refreshing, I think, for all of us to have convened here today for the purpose of discussing a successful program.

Usually, it seems, I find myself in the other kind of meeting -- the kind that's dealing with problems not yet solved. Of course, I don't suppose any of the rest of you have experienced that situation.

One of the important things that I hope will be brought out here today are the specifics of how a great variety of government and industrial organizations have worked closely together to a common goal.

The achievement of that goal has been recognized in various ways -- not the least of which were the ceremonies conducted at the White House shortly after Major Cooper's flight on the 21st of May.

I thought that this group would find interesting a film clip of that occasion and I would like to show you the clip at this time, just to give you a feel for the situation.

(Whereupon, at this time the film was shown.)

I think this was a significant culmination of the activities in Washington. In reality it was an award honoring all the participants in the Mercury program.

Now, let's turn back to the beginning.

It has become a cliche, of course, to say that complex technical programs, such as Mercury, require teamwork. Yet, all of us involved in such work know that this is one cliche that is based on bedrock fact. And all of us know, also, that in these teamwork situations there's a certain amount of friction that is bound to develop. That's just human nature.

Yet, in the Mercury program we have seen that such frictions can be reduced to a minimum, and here again I would hope in our discussions today we can speak frankly of these "organizational interfaces" and isolate the reasons why things went well in this program, so that the proceedings will serve as a useful handbook for future program planning and execution.

I cannot leave this point without laying special emphasis on the very fine relationship which the Space Systems Division has had with NASA, and especially the Manned Spacecraft Center at Houston.

I think the interface between the NASA and Air Force people has been extraordinary. We've had, it seems to me, a minimum of meetings and a maximum of mutual trust -- when a phone call between Walt Williams or Bob Gilruth and our people, for instance, would quickly resolve problems or matters of procedure.

Because many of you here have not been directly involved in this program, I think it will be helpful to you if I outline, in very broad terms, the organizational relationships involved.

First of all, the basic responsibility for the Mercury program rested with NASA, and specifically the Space Task Group at Langley, and now the Manned Spacecraft Center (Slide 1).

When the Mercury program was set up in late '58, the Atlas was the only rocket then in development which could undertake the job of launching orbital missions.

NASA (MSC) USAF (SSD, AFSC)

Slide 1

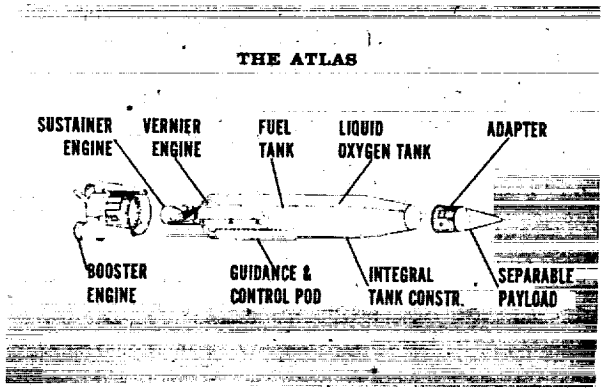
The Atlas had then been under forced-draft-development for many months, and it is interesting to note, I think, that the Air Force had undertaken this program in 1954 under fairly controversial circumstances.

At that time there was a substantial number of respected members of the scientific community who felt that an intercontinental missile was a risky proposition indeed, and that if it could be made to work at all, the time required would greatly exceed Air Force estimates.

Nevertheless, the Air Force, confronted with its responsibility for maintaining this nation's strategic deterrent capability, believed that with proper application of the nation's resources, an ICBM was within our technical capability. So, the Air Force went ahead full bore.

If it had not, this nation might not yet have put a man into orbit. Almost as a by-product, you might say, of the main purpose of the Atlas development program.

Further, the design of the Atlas itself was controversial, especially the unconventional "stage-and-a-half" design, and the large single tank, feeding all engines (Slide 2). And this tank had no interior structure, depending upon the internal pressurization to provide structural rigidity, as well as the head pressure required by the pumping system.



Slide 2

As it turned out, these features proved perfectly satisfactory in flight test of the weapon system.

But what is particularly interesting for us here today -- and I don't believe this has heretofore been brought out specifically -- is that these very features, by sheer good fortune, turned out to give Atlas the ability to launch the orbital Mercury payload.

The tank design gives Atlas a favorable mass-weight ratio, which means a minimum of dead weight in the booster, to better achieve the payload capability.

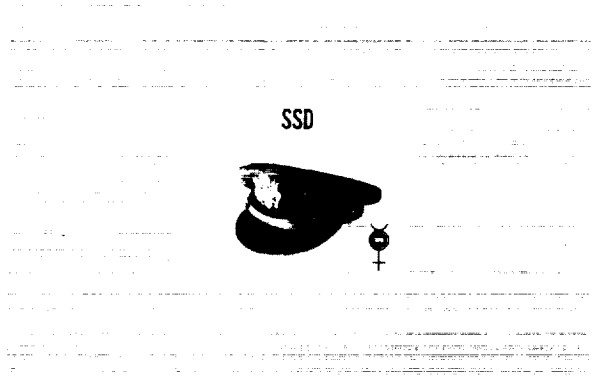
And since both the booster and sustainer engines draw fuel from the single tank, Atlas provides a wide selectivity in booster and sustainer burn times, which can be tailored to Mercury flight profiles.

And, of course, this design allowed all engines to be started on the ground prior to launch, which provided further pilot-safety assurance.

So, when the nation's space program required an orbital Mercury booster, the Air Force was able to provide it.

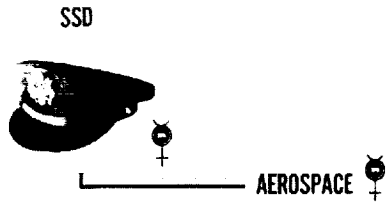
Obviously steps had to be taken to man-rate the vehicle, which was designed originally as a weapon system, against a punishing time schedule.

To bring this about we set up a Mercury Program Office, in what was then the Ballistic Systems Division, now Space Systems Division, of Air Force Systems Command. (Slide 3.) This office was built up to five officers, headed originally by Lt. Colonel Robert Brundin, and now Major, soon to be Lt. Colonel, Toby Gandy, both of whom are with us here today.



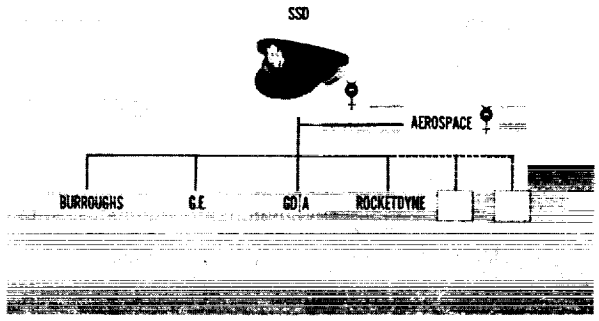
Slide 3

As technical staff we had the fine support of Space Technology Laboratories, originally, and now Aerospace Corporation, which acquired the services of many of the people who had been on this program with STL. This group has been headed by Ben Hohmann, who is also with us today (Slide 4).



Slide 4

The Atlas Weapon System program had been handled by a group of associate prime contractors. The work of some of these, involving re-entry vehicles and other weapons applications, was not germane to the Mercury program.



Slide 5

Those associates who were involved are shown here: Burroughs Corporation had the guidance computer, General Electric the airborne guidance, Rocketdyne Division of North American the engines, General Dynamics/Astronautics the airframe, autopilot, assembly and checkout, integration, and launch (Slide 5).

Because of its widespread role in the total effort, Astronautics designated a special Mercury Booster Program Office, which included such men as Charlie Ames, Phil Culbertson, Howard Newman, and Dick Keehn.

Two other Air Force organizations were also deeply involved, the Atlantic Missile Range and the 6555th Test Wing, which carried direct Air Force responsibility for overseeing launch operations. The actual launches were carried out by an industry team headed by GD/A as the integrator. The GD/A team was run first by Tom O'Malley and later by Cal Fowler.

So, as you can see, the existence of the ongoing Atlas program put the nation many jumps ahead of where we would have been if it had been necessary to create a Mercury booster from scratch.

But, obviously, changes were necessary to convert a weapons-carrying system to a passenger-carrying system.

I think the most fundamental change that was required was one of point of view.

In developing Atlas as a weapon system, our main taskmaster was time -- to develop as quickly as possible an operational vehicle that would deliver a specified payload a specified distance with specified accuracy.

And, incidentally, those goals were met ahead of schedule. The original requirements were considerably exceeded in range, payload, accuracy, and dependability.

But with the Mercury assignment, our point of view changed -- time was still important, but with a man riding the bird, not to mention national prestige, dependability became absolutely paramount.

So, our pilot safety program was designed to insure that dependability and to provide a capsule-jettison capability.

Other speakers on today's panels will describe in some detail just what this program was and how it was carried out.

The part I should like to emphasize is the overriding importance of personnel motivation in the successful prosecution of this program.

It is, of course, popular to say that, after all, it is people who get the work done. But often we say this and at the same time forget it, especially in complex technical programs and in big organizations.

But this Mercury booster program has shown us dramatically how important people are and how much they can do and how well when they are motivated positively.

The biggest factor in this, I am sure, was the nature of the program itself. Here was an assignment to awaken the imagination and enthusiasm of every person connected with it -- to put a man at the apex of over 350,000 pounds of thrust, to accelerate him to a speed of 26,000

feet per second in a matter of five minutes, to guide him to a point some 100 miles from the earth's surface, and finally, to release his capsule into an orbit outside the earth's atmosphere.

In the epochs of man's experience on this planet, only now in our time were we ready to undertake this adventure beyond the atmospheric shell of our particular planet.

And, if that in itself were not a sufficient challenge, there was the matter of national prestige. The Russians were first into orbit and no American likes to run second best.

So this was going to be a tough race -- and it still is -- and I think that has had a very strong motivational effect on all of us.

So these motivational factors were very helpful to the people assigned the responsibility for making the Mercury booster program go. And the nation was very fortunate in getting men on this program who were equal to the challenge.

It is especially interesting to note that there have not been large numbers of people assigned to any aspect of the Mercury booster program, in our headquarters or in the industrial organizations.

From this, even if we did not know them personally, we can deduce that they were people who had the ability to engender action throughout their respective organizations -- they were the "whips," you might say, who lobbied the Mercury cause through the intricacies of their own organizations.

Obviously their efforts would not have been effective if they had not had the support of the top people in their respective organizations plus discipline all the way down the line to carry out the Mercury plans.

The efforts of General Dynamics/Astronautics furnished a typical case study of how widely and deeply this kind of action can go in an organization.

The details of these efforts are being described in workshop sessions today, but I think it is worth-while to review the various ways which

GD/A management found to "get the word" on Mercury to every facet of its organization -- and to perform to the Mercury standards without interrupting the work it was doing on the Atlas Weapon System, as well as other programs in progress in its facilities.

Great credit in this program is also due to the Astronauts themselves, who made personal visits to the Astronautics plant, as a group and individually, and made it a point to get out and talk with the people actually doing the work -- as any good test pilot would, of course. But the effect of their evident interest, and the knowledge that these were the men who were going to ride that Atlas, was certainly a strong factor in giving these people a sense of the responsibility they bore in building this launch vehicle.

In summary, I think in the booster portion of the Mercury program we have the perfect example of the truth of the old adage, "Plan the work, and work the plan."

NASA's plan for the program was well conceived and technically sound. It capitalized on the resources and technical knowledge available in our nation, especially the existence of the Atlas vehicle. It provided for sensible interfaces between principal organizational elements doing the work.

Insofar as the booster was concerned, we in the Air Force were able to adapt the Mercury plan to our existing government-industry structure without interfering with our weapon systems efforts. By applying well-motivated people to the task, the program results were remarkably close to original targets.

And while the Mercury program is officially ended, the benefits from it will be with us for a long time to come.

The accumulated knowledge gained from Mercury is already being fruitfully applied to many other programs. And this meeting here today will accelerate the dissemination of that knowledge.

I commend you all for taking time from your busy schedules to come and participate, and I trust that this will be active participation, that

you will wring from us who have worked on the Mercury booster effort all the know-how which we can provide.

Let us not let the many findings of this highly successful program be dissipated in our efforts to plunge ahead on new tasks. Today we hesitate for a moment to sum up. And if we do it well, our work tomorrow will be rewarded.

Thank you.

MR. McKAY:

Thank you, Colonel Hoffman.

Our next speaker is Mr. Walter Williams, Deputy Director for Mission Requirements and Flight Operations, Manned Space Center, Houston, Texas, National Aeronautics & Space Administration.

Walter.

MR. WILLIAMS:

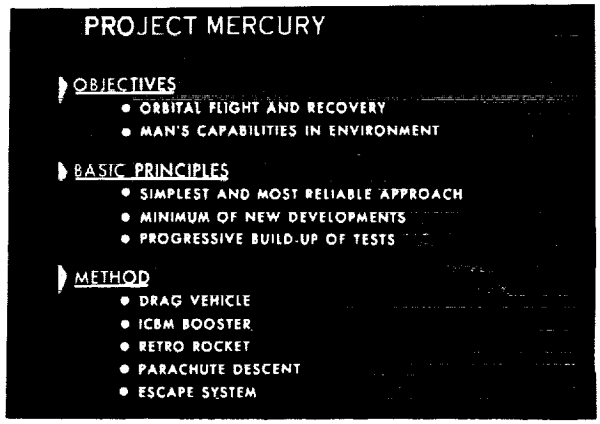
I think in setting the tone of this meeting it is important somewhat to discuss the history of the program and its evolution, since the flight of Major Cooper in May really culminated an approximately four-year evolutionary process, and looking at the audience I do this with a few misgivings because there are many in the audience who made this history, but I will try to give it as I saw it.

I am sure there will be some repetition of what Colonel Hoffman has said and of what Jim Dempsey plans to say.

I think one thing we can all agree on, Mercury was quite a technical exercise, but I think equally important was the management exercise, and it very definitely was an exercise in human relations, because out of this I think we talk of, let's say the term -- both of them are hazardous terms -- I can call it either unification, which those in uniform consider a dangerous term, and then there is always the term integration, but this quite well describes what we did, I think.

I think it might be well to go back to a slide we used several years ago which sort of outlined the Mercury program, its objectives, and what we thought the approach was and should be.

If we could have that first slide.



Slide 1

All right, now, I can see it (Slide 1).

Well anyway, to start with, the objectives were orbital flight and recovery and to demonstrate man's capabilities in the environment, space environment. Colonel Hoffman very nicely showed this White House film and in that I think the President quite clearly stated that we had demonstrated these objectives and that man had a place in space and that we had proved his capabilities.

But I think for the purpose of this discussion the other items on this slide are perhaps more important. What were the principles that we started with? We tried to take the simplest and most reliable approach.

When you analyze the mission, it was not a simple mission, particularly not in 1957-58 when we were beginning to think about doing it. It looks pretty small now, compared to some of the newer programs, but not at the time.

We knew that if we were going to do it in any time at all we would do it with a minimum of new developments; that we would use -- and I will put quotations around this -- "on-the-shelf items," and that we didn't have time to develop new equipment and that as in any development program of this type, particularly a flight test development, we would attempt a progressive build-up of testing.

The method that we chose, again considering timing and simplicity, was to use a drag vehicle -- that is a ballistic re-entry rather than a winged re-entry. As you know, we knew we needed retrorockets to de-

orbit. I will skip the booster item for now.

Again we chose the parachute descent, which was an outcome of having selected the drag vehicle. Of course we knew that with that we had to go to the water landings, initially because of the land impact problems; we knew since we selected an ICBM booster, we had to provide a good escape system.

We knew that we could not in the time that we felt we should do this program, develop a new booster or a space booster. We knew that we had to look to the ICBM program to provide us with the capability. In reviewing this we settled on the Atlas. Colonel Hoffman mentioned some of the reasons; I can repeat those and perhaps give them a little bit from our point of view.

One, of course it did have the performance capability to do the job, and although we didn't know, it grew in performance because our space craft grew.

We liked the idea of having all the engines running at lift-off, because at this point in time the less questions on the matter of altitude starts of rocket engines the better.

Because of the concentrated effort of the Air Force, the Atlas was in an advanced state of development and we had then the total of the weapons systems technology to draw on; in addition, it was a continuing program that we knew was going to end up in an operational ICBM, and out of this we knew that even though at the time the Atlas, in our minds and I think in everyone's minds, left something to desire, we knew there was a concentrated effort to continue the development and that this would help.

So, for that reason, we chose the Atlas and then set about the problem of, "how do we use it," and the most important thing, which you will hear many times today, which I don't know that it can be really defined, and that is this phrase "man rating."

We knew several things. We knew that we were going to fly a man; we knew that we needed reliability, if you will, or dependability over and above that at least that had been demonstrated at this point in time in the ballistic missile program. We knew that we had to provide for the safety of the man.

Out of this we devised a simple escape system, working with the booster complex, an automatic system was developed in order to get the man away from it; in addition -- and this was very important -- we knew that we needed a good Atlas if we were to do this mission, and I think this last phrase is what much of the discussion today will evolve about.

Now, again going back, we had to get started. We had to bring together groups of people that had never worked together before. Bob showed a chart with a hat and a cap, if you will, but what did this consist of?

Well, I think you have to look at the times. NASA is an agency that was newly created, in fact, probably a matter of a few months old when the first discussions took place with the Air Force. The Air Force men were heavily committed in this ballistic missile program and had a very real mission just in that alone to develop the ballistic missile; they couldn't help but look askance at this NASA group that had this new mission, manned mission, that were primarily at the time research oriented or, if anything, aircraft oriented with probably a lot of wonderful ideas on what should be done in the ballistic missile program or in the space booster program, but really not too much experience in it.

So from their standpoint certain ground rules were laid down of how the program would be handled; that they would deliver to us a space craft in orbit; that we would not tinker with the Atlas; that the only changes, if any, to be made would be those to provide escape and provide pilot safety, and I think on our side of it, I know in my own case, with a background in aircraft, aircraft flight testing, we couldn't help but look askance at the missile people at that time, these big balls of fire on launching pads, and shortly thereafter, were not the most reassuring thing in the world, and again I think this was a problem, not only technically, but one in human relations, and I think the thing that evolved out of all of this was a very important thing to this and that was the feeling between the team members of mutual respect and trust and I don't think anything can pay off like this.

In fact, I will ask that Air Force friends, as well as space people, and GD/A forgive me at times when I use the term "we" because I don't mean we, NASA, but I am talking about we as the total Mercury team.

I think all during the program we, as we came along, we found it very difficult to find the organizational lines and so in this talk, as I say, "we" I am not quite sure exactly which organization, I mean, as I discuss this evolutionary process.

So as we got started we knew we had interfaces; we knew we had to have a means to solve them. I will say one thing we did was try to minimize the interface, the hardware in a phase, in order to get more people working at the same time, but we did develop a system of panels to bring together the right people; discuss the technical details.

We had basically three Mercury-Atlas Coordination Panels. There was one concerned with design coordination, scheduling, fabrication, checkout, and countdown procedures. There was another concern with safety, pilot safety, emergency procedures, and landing and recovery, communications; another was booster performance, air trajectories, and flight loads.

These panels initially met quite regularly; were represented by people from NASA, McDonnell, space craft contractor, Air Force Ballistic Missile Divisions, Convair/Astronautics, using the names of those particular organizations at that point in time.

In addition, at the Cape we set up a Mercury-Atlas flight test working group, again with the same representation, which was to solve the problems, and particularly those connected with the launch complex at the Cape.

I think an important thing about these panels is that they met when there was something to discuss and we kept them in existence only as long as they were useful. So often in a program such as this, or any effort such as this, panels, committees, working groups are created that outlive their usefulness; they meet for the sake of having meetings and so on, but these were not of this type.

And I think as the thing moved along and as we began to get into an operational phase, it developed more into a direct working relationship between the key people at SSD, Aerospace, GD/A, NASA, to where we were not pulling isolated groups together, but having joint meetings. This is true particularly as we got into the flight test phase where we

reviewed the missions; where we reviewed the data from the flights; where we met on particular problems that really concerned themselves with refining the Atlas and this is involved, because there were performance improvements shown or required really on each flight. After all, our space craft grew from the original estimate, I believe, of 2,400 pounds to where in Cooper's flight, the weight was around 3,050, and actually on this flight we had a larger performance margin than we had on any previous flight, so we still had growth and I won't argue about whether or not we use it.

We developed our procedures as we went along. Some of the things that came out of this, I think, for example, we adopted a policy -- yes, there were changes, but because they were required in the weapons system; they were required then on occasion on the space booster as well, in the Mercury booster, but we made it a practice never to fly a new change for the first time on a Mercury booster.

Another thing that we did early was realize we had to handle each flight as though it were a manned flight, because if we didn't and didn't apply the same safeguards and precautions we would never get to the manned flight.

This was procedure at the factory; this is procedure at the Cape, the in-flight procedures, and I think a very important one, and this one I know will be touched on today too, is that as a hard rule we did not fly where there were unanswered problems concerning the status of any of the hardware. We probed and came up with answers for any anomaly, for anything that deviated from the norm, and I think all of this evolves itself to the point of meticulous attention to detail and I think you will hear that a lot today.

The matter of motivation has been discussed and you can't discuss meticulous attention to detail without discussing motivation, why such attention, and we accomplished this in a number of ways.

The astronauts have been mentioned. Yes, early in the program they made a visit here to the West Coast complex and this visit and a phrase that came out of it, and I believe it was attributed to Wally Schirra, in describing the employees here at GD/A, anything that the astronauts would want or request in this effort, his answer was, "Do good work,"

and this became a slogan used; I am sure Jim will talk about this, but it was a slogan used throughout the plant. I know it has its effect.

The man-rated teams will be discussed; the detail processes we went through. I think we reached -- it wasn't all easy; it wasn't all rosy as on the film as those of you who were with us through it know. We took our knocks and in the 9-flight program we had two failures. MA-1 was a dynamic structural problem. It was an unanswered problem but we weren't smart enough to ask the question, so we had to learn from that, and I think then our next flight was successful with some structural mods, and I think that with the work we had to go through to make that flight, I think it was where this Mercury team began to come of age a little bit.

I think then our next flight was a failure. Well, I know it was, April 25, 1961, but I think several things happened in that month or around that time that I think really brought to the forefront on this motivation question, the business that we were really about.

For one thing, on April 12th, Gagarin orbited the earth. There was no question as to the Russian intents. In fact, they had done it; they had beat us.

This was to be our first attempt to launch an unmanned spacecraft; we had a failure, and I think it would be fair to say that it was a program failure. I think it would be fair to say that it probably failed in a quality control area.

Meanwhile, something happened good on our side of it, because shortly after that we had Alan Shepard make a ballistic flight, and I think that the thing that did more than anything else was -- you get so close to the fire in these things that you forget what is going on in the rest of the world in some ways, and I think the thing the Shepard flight did was show us what this thing was really all about from the standpoint of national prestige, national enthusiasm, a lack thereof.

It also, I think, set a precedent that has been followed ever since and is really a precedent in the research and development and that was that we did this completely wide open, every detail of this thing was on live television and with the world's press in attendance.

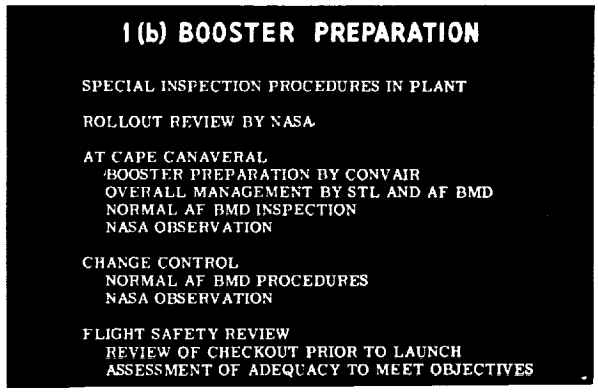
I think all of this, all of these things happening soaked back in and I think this particular point in time was a real turning point in the program and a real turning point in this working relationship between people involved, but I don't think the motivation can be underestimated, as well as the cross-feed between organizations, and in this case the cross-feed between the weapons systems programs and the space programs, communications, people talking to each other; people wanting to do a good job.

Quality, I think, will be a word discussed heavily today. I think we know that we want quality assurance; we want quality control. This is inspection and I use a cliche, you cannot inspect quality, and I don't think it has ever been, into hardware. It has to be there and I don't know of any case that is more true than these very complex space vehicles we deal with.

Getting down to the level, it has to be down at the grass roots level; the motivation has to be at the management level, but it has to reflect itself down. A great example, the wiring in an autopilot circuit, there are so many wires; there are so many pins, really the only guy that really knows that it is a good piece of work is the guy that did it himself, and so it takes the motivation down at that level.

And I think all of us working together, plus this national prestige thing, the competition with the Russians accomplished this in Mercury, although it wasn't easy and the problems were never completely solved. As you know, we had problems right up until this last mission.

I think talking about the flight test part of it a little again, I'd like to here go back to an old slide to show the principles we laid down for the booster preparation. We would like to talk then about how the launch organization evolved, and let's see this one (Slide 2).


1 (b) BOOSTER PREPARATION
SPECIAL INSPECTION PROCEDURES IN PLANT
ROLLOUT REVIEW BY NASA
AT CAPE CANAVERAL
BOOSTER PREPARATION BY CONVAIR
OVERALL MANAGEMENT BY STL AND AF BMD
NORMAL AF BMD INSPECTION
NASA OBSERVATION
CHANGE CONTROL
NORMAL AF BMD PROCEDURES
NASA OBSERVATION
FLIGHT SAFETY REVIEW
REVIEW OF CHECKOUT PRIOR TO LAUNCH
ASSESSMENT OF ADEQUACY TO MEET OBJECTIVES

Slide 2

All right, this slide, I am not quite sure who prepared it, but it is the things that we wanted to do with the Atlas booster.

We knew that there should be special inspection procedures in the plant that should not interfere with the normal production, but at the same time these had to be treated, I don't know how this term "rollout review by NASA" came into it. It has been a joint effort between NASA, Air Force, and Aerospace, and primarily NASA accepting this booster from the contractor.

At the Cape the basic booster preparation was done by Convair; the overall management, of course, was Air Force Ballistic Missile Division and STL, later to become Aerospace, as we all know.

We would provide normal Air Force BMD inspection. We would observe, and "we" in this case is NASA; change control, we would use normal procedures. NASA would know what was going on.

The flight safety reviews will be talked about more and this is mainly a review of check-out prior to launch, and really what this is is a review of the complete history of this particular AF BAID, what happens to it from the time it became an identifiable article until the time we were ready to light it, and then of course the assessment of adequacy to meet objectives.

This is basically a performance evaluation.

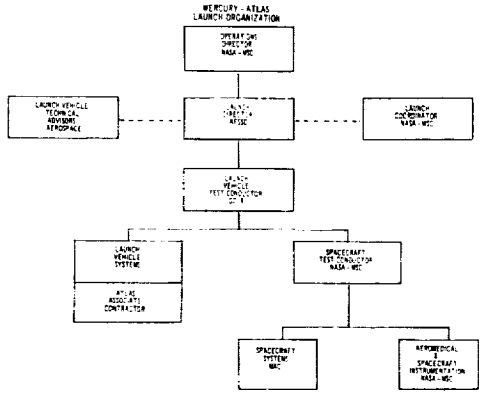
Now, to implement this, I think I can take a few moments on this (indicating) slide. This normal AF BAID inspection became quite a bit more than this.

We know, for example, that in our boosters there were always officers from the test wing on the pad working with the Convair or GD/A crew on a multi-shift basis, as required. We developed, I think, what we should all be proud of, and particularly the crew themselves, really a select crew for these launches. The crew remained essentially an integral unit throughout the program. There was very little turnover in the crew and I think this in itself happened to pay off.

Here again, Colonel Hoffman mentioned motivation, motivation by the astronauts. One thing we always felt was one of the very important aspects of the preflight preparations at the Cape was the fact that the astronauts who were to take the mission went down there and worked with the preparation crews from the time the space craft arrived, usually the booster came later, the space craft was there; the astronaut himself participated in the check-out; he later participated in the work at the pad with the booster, and he became not someone that these people saw as a photograph somewhere in a silver suit, but a real, live guy working with them day by day that they knew and understood and knew he was the man that was going to sit on the front end of this thing and I think this was important.

I think we can look at the launch organization. Now here is the time where the -- and I would like to comment on this, this is a pretty direct line organization, and I think shows integration or unification, or call it what you will, but I don't know how else you conduct an operation unless, and it is not the fact that I happen to be the pinnacle of this one, but there has to be somebody in charge of the total thing and I think this must occur.

I think we've seen evidences where there are joint operational programs or maybe the word is cooperation where the various participating groups coordinate. (Slide 3.) We coordinated and we cooperated, but we also had a direct line relationship, but I think you can look at the titles and I think you look at the identification under them. It makes it interesting.



Slide 3

We had the Operations Director; that was a NASA individual.

We had the Launch Director, and mind you this is only the launch activity phase of this total operation.

We had this same sort of integration elsewhere. We had the Launch Director who was from the Air Force's Systems Division, actually the test wing at the Cape. He was supported by launch vehicle technical advisors from Aerospace and our own launch coordinators.

The total test conductor, the guy really doing the work, that is pulling everything together in the blockhouse, was a GD/A man.

In addition then, we had the launch vehicle systems people that were GD/A and the associate contractors involved, at least on the other side; we had a space craft test conductor who was a NASA man and in turn had working for him both McDonnell people and Spacecraft Systems and NASA people, and in the Aeromedical, spacecraft instrumentation, and usually an astronaut on the communications channel.

So we had various organizations spotted through this, but nevertheless, they worked together, and as I say, you pretty well forgot the color of the guy's suit or the type of hat he was wearing. I think that was terribly important toward working.

I realize I have rambled a lot, but this was put together on a quick basis. I am trying to point out the things that I thought were important. I think in the future we have learned things from Atlas.

Obviously, we can't repeat too often Schirra's -- if it was Schirra's -- comment, "Do good work." I think we have learned some management lessons, how to get people to work together.

I think we are very lucky that although the contractors changed, the booster contractors changed in Gemini, we will be working with many of the same people we worked with before.

The NASA team is relative unchanged. We have many of the same Air Force Systems people with us and we have many of the same Aerospace people with us. So, I think we will be able to maintain the continuity, but I think again when you start with an existing system, the big problem is to make it good and make it very good and it takes attention to details, really, at all levels and I think that will be brought out many times today.

Thank you, very much.

MR. McKAY:

Thank you, Walter.

Mr. Jim Dempsey, President of General Dynamics/Astronautics will be the last speaker.

MR. DEMPSEY:

I am going to talk on the same subject, representing the point of view of one of the contractors involved in the program.

I was thinking while watching this projectionist back here, if Gordo thought he was busy during his flight he ought to have to try to juggle three different projection systems on one table. I think he is doing a remarkable job.

We established early in the Mercury program in our place a special identifier, which you see here.

It consists of a seal of reliability, which we have used at Astronautics, for some years, since about 1955, in the center (Slide 1).

And the external symbol, of course, is well known as the astronomical symbol for Mercury.

We used this in many different ways, but I think this was one of the important aspects of establishing the fact that we did have a special program and it came to be recognized everywhere. It was used as something that required particular attention. This I believe was one of the fundamental lessons that we learned.

Slide 1

Now the Atlas was -- the Weapons System was the basis in the beginning of the Mercury booster and there was, of course, the normal amount of experience which had been accumulated and continued to be accumulated and brought to bear on the Mercury program. That's all fairly straight forward and I just repeat here some of those things.

There was, of course, a significant amount of system component and parts design. There had been the normal activities of system integration of several associate contractors, subcontractors, and other activities involved.

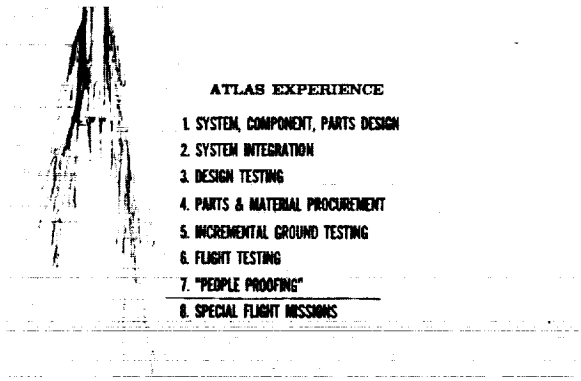
There had been a great deal of design testing accomplished, most of which was applicable to the booster program. We had a background of parts and material procurement and in one sense had an advantage here, because we were able in some cases to make selections of, let's say, the most nominal part, which is a kind of a curious word that we came to use in order to make sure that we had the best parts for the Mercury booster.

We had accomplished a large amount of ground testing of components and subsystems before flight, which also added to our basic knowledge of the system performance.

We had accomplished a great deal of flight testing at the time the program began. There had been 23 flights of the Atlas and by the time of John Glenn's flight, 116.

We had a great deal of experience in proofing the people in terms of checkout teams, launch teams, understanding that you had to have written procedures and you had to make people follow them and get them to understand it was important to do that, and all this sort of thing, and finally we had had a number of special flight missions which simply provided such useful experience in flying a booster in a different load than its basic weapons system design (Slide 2).

Examples of these sort of things were Thor flights, Atlas-Agena flights, long-range flights of the Atlas itself, and so on. This was the basic experience which was available in 1959 when we undertook the Mercury program, and we began to build on this experience, along the lines that Bob Hoffman and Walt Williams have described.



Slide 2

Teamwork, I will add that word to the two that Walt used. This is kind of an overworked word too, but I believe sincerely that this was the fundamental characteristic of the Mercury program which perhaps exceeded any other. All of the organizations involved and all of the people involved were held together by a common goal, that of getting the astronauts safely into orbit and safely back, and I believe that overrode in all our minds any other aspect of the program.

Personnel will be a subject to be discussed in much greater detail today. It involves the proper people, and proper jobs, training, motivation, recognition, all of these aspects of personnel activities were very important.

Our special design features for the Mercury booster consisted simply of removing those characteristics or features of the weapons system which were not involved or required for the Mercury mission and adding to the booster the abort sensing and instrumentation system, or the ability to increase the pilot safety of the booster.

We did not make any other special changes.

We established, and I use the word "we," in the same sense that Walt did here, a special quality assurance program; involved all the people in the program. We again laid special emphasis on employee motivation. We established special acceptance procedures, which was a team acceptance activity on completion of the booster in the plant.

We had special data accumulation and review procedures. We weren't satisfied until we could explain every glitch that occurred in the many thousands of feet of tape and data and we established special handling procedures for components and things of that sort.

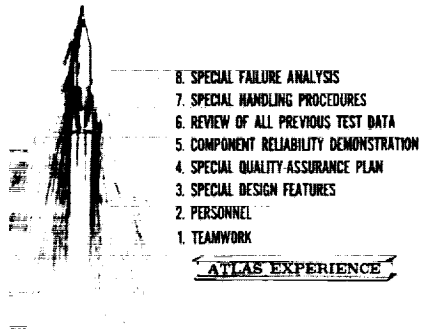
As Walt just mentioned, we did not fly any system or component on a Mercury booster flight until it had flown on some other flight. That I think was an extremely sound program. It may be harder to achieve on programs where you don't have any other flights to fly them on.

We had special data review activities in which we accumulated all the receiving inspection data, systems test data, vendor data, the whole freight carload of data, which was part of the history of the particular booster and was reviewed and accepted as a part of the general booster acceptance operation, a very important consideration in knowing just what that booster is like.

As I mentioned, the special handling procedures were established which involved the identification of a number of critical components, marking those with this Mercury symbol that I showed at the beginning, so that everybody who picked up one of those things knew that he was handling a critical part and could act accordingly.

This, incidentally, was one of the important aspects of people motivation. It is awfully easy to drop a gyro about six inches on the bench. It won't show any more and it may not show when you test it the next ten times, but it may break the eleventh time, so it is important for people to understand that that kind of activity has to be reported and it is important, incidentally, that the person know he is not going to get fired for an honest mistake -- just if he keeps repeating it too many times.

Well, finally, a special failure analysis program was undertaken in which any failure that occurred on any component while the booster was in the process of manufacture or check-out had to have a complete failure analysis prior to the acceptance of the booster. Otherwise we would not accept the part (Slide 3).

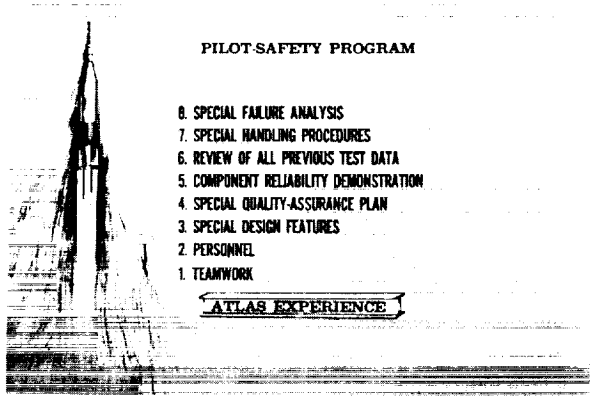


Slide 3

The idea of failure analysis was in work, but we had to know before we accepted the booster the basis for this failure so we could decide whether we wanted to take the booster the way it was or do something differently.

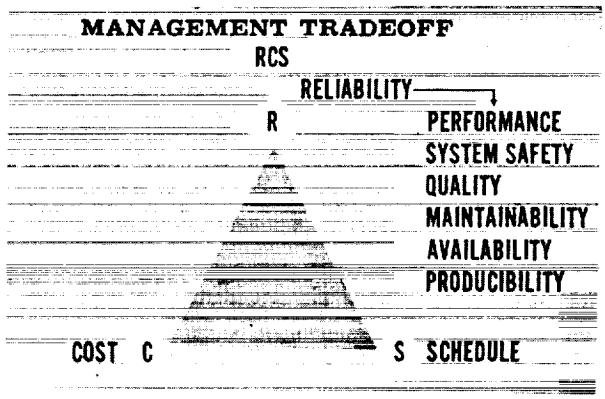
All of these special activities together summed up to make the pilot safety program insofar as the booster is concerned and there will be more discussion of that later on today, but I think it is clear that these special activities added to the general teamwork of all of the organizations and people involved with; in some measure responsible for the success of the program (Slide 4).

Now I want to touch on a couple of factors which seem to me to have developed through this and similar programs over the years.



Slide 4

We have come to believe that any program which is undertaken involves, and any management decisions or management tradeoffs involved in any program involve normal conflicting points of view on cost, schedule, and reliability (Slide 5).

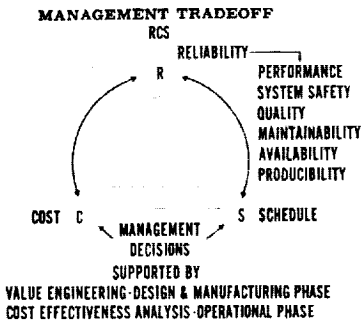


Slide 5

I point out here that reliability includes a number of factors, performance, systems safety, quality, maintainability, availability, and producibility, and I suppose you could make that list longer, but that is a pretty good list.

Now the reason we use the term "reliability" as the third

point in this RCS triangle is you can have any of these factors that I list as relating to reliability without having reliability, but you cannot have reliability without having all those.



Slide 6

So in our organization and in the way we operate and think, we consider reliability as the all inclusive third parameter, which together with cost and schedule, make up the management problem, you might say.

Now we feel that the management actions that we take every day on all of our programs affect this management triangle in some way or other. Maybe even by default, but certainly if one gives considered decisions, it is possible to decide which one of these is given primary consideration (Slide 6).

We can even effect, of course, the performance by such things as value engineering and design and manufacturing phases. We consider cost effective analysis; we consider worker motivation; we consider all these things in our attempts to rotate this wheel, or possibly to keep it steady.

And in the evolution of the Mercury booster program it might be considered something like this.

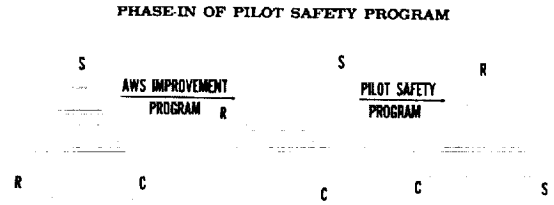
As Bob has pointed out, and as I think is generally known, in 1955 we undertook the Atlas Weapon System with one paramount consideration, to get an operational intercontinental ballistic weapon system as early as possible. Now throughout, of course, one is concerned with reliability and one is concerned with cost, but as they say in the Navy, this is ranked with, but after, schedule in the case of starting the weapons system program.

Now that, of course, refers to the initial phases of that activity.

As the weapons system went into operation, of course, one becomes very definitely more concerned with reliability and with cost and these things begin to take paramount importance through such things as update programs, Category 2 and Category 3 test programs, things of that sort.

We began to tilt that triangle a little and finally in the case of Mercury, as we add the pilot safety program, it became quite clear that reliability was the concern which was uppermost in all of our minds (Slide 7).

Now how and what are the ways you do this? Well, the same RCS triangle here simply indicates that people are the ways with which one accomplishes these sorts of things.



Slide 7

It is an old story that management is the accomplishment of things through people, and if we think about the management activities, experience, skill, organization are the kind of things that are involved in the design, value engineering considerations, design reviews, testing, all of these are the kind of things that one can do and in the worker area, the general motivation, education, training, all of these are the kinds of things that one does in order to try to keep that triangle stationary in the position you want it to be.

There is a little squirrel shown on the top of that (indicating) which sort of represents the unknown things that can happen to you (Slide 8).

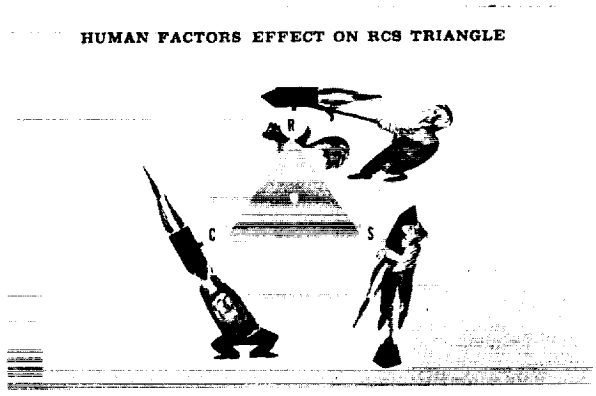
I suppose for this audience we should have replaced that by a diesel generator.

(Laughter.)

Now, let's talk about then the thing which is of interest to me as one of the major things that I do, which is the concern of organization of the people, and how Mercury has effected that in my mind.

We started with the Mercury program in 1959 with an organization which included a group of functional departments of a reasonably classical organizational structure in the aerospace industry in which there were such things as engineering, and operations, and quality control, and contracts, and a comptroller, and all that stuff (Slide 9).

Now we established a project engineering group in the engineering department for Mercury and that was the beginning of the project organization activity insofar as Astronautics was concerned, (Slide 10) because you might say really before that time our entire division was a project organization concerned with building the Atlas Weapon System, but as we came to see that the general question of project identification, both within the organization and with respect to the outside world, became



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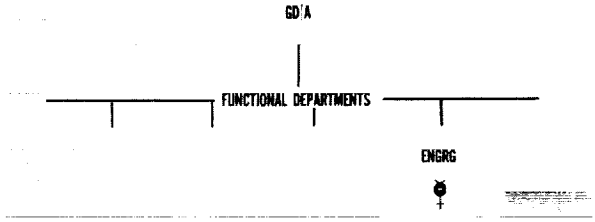
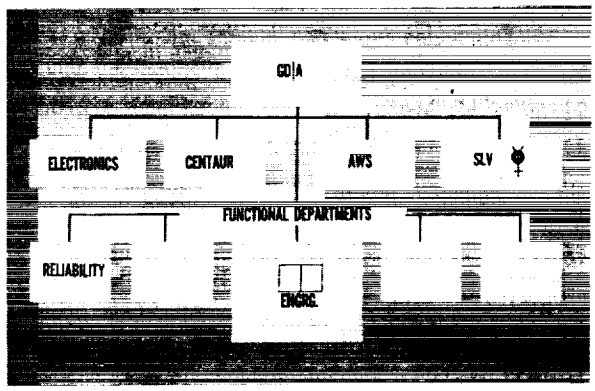


Slide 9



Slide 10

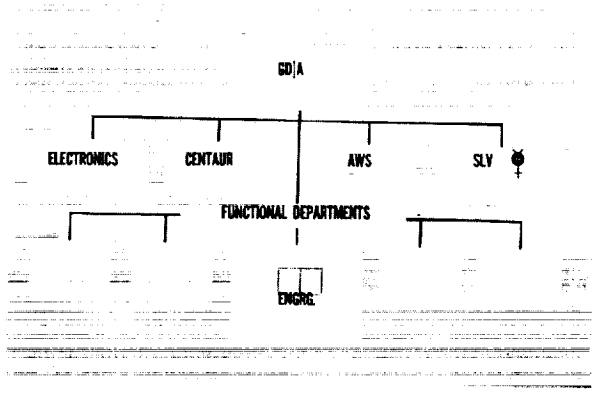
more and more important and it became important to know that, to establish that the person who has the responsibility for accomplishing the project must also have the authority for accomplishing the project.

We have gradually evolved in our organization into a project organization of a fairly disciplined nature at this point. We have four project organizations, the AWS refers to the Atlas Weapon System; the SLV refers to the Space Launch Vehicle project of which Mercury was one of the integral parts.

Now you will notice I still don't have a complete project organization in the sense that every contract has a project organization, but they are grouped by similarity of product and similarity of customer, that I think is important, because one of the problems that a contractor has in the world is to do things like his customer wants him to do and one of the ways that one accomplishes this is make it clear to this customer that he has somebody whose principal aim in life is to do his job the way he wants it.

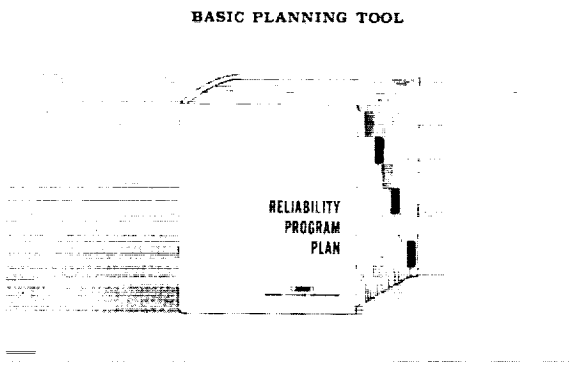
You will notice that we do still have some small projects contained in our engineering department and if they ever become a hardware and ongoing operation that takes the major percentage of the resources of the Division, they would also become that kind of activity.

Now one of the functional departments of the five that we have is Reliability Control and I will have more to say about that in the management session, (Slide 11) but it is through this Reliability Control Department that we have come to believe that fundamental lesson that we have learned is that of establishing the reliability plan in great detail and then, as Walt pointed out and with which I thoroughly agree, meticulous attention to detail



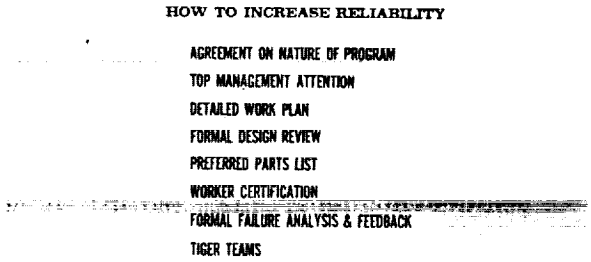
Slide 11

in the execution of that plan is one of the keystones of achieving a reliable program or a high reliability (Slide 12).



Slide 12

Now, how to increase reliability. If I were to try to summarize what I think our organization has learned from the Mercury program on how to increase reliability, I would mention these points (Slide 13):



Slide 13

First of all, it is of fundamental importance to agree with the customer in the beginning and with all of the other people in the program on the nature of the program to be undertaken. By this I mean the relative position of this RCS triangle, what is important to the customer, and then that becomes important to you.

One must establish top management attention to the subject of reliability if it is a program in which high reliability is a primary concern and there are some ways in which we do that which I will talk about in two minutes, later on this morning.

One has to have a detailed work plan. You cannot solve a general problem. One has to have a specific work plan and enough details so that the agreement on the nature of the program is made easy.

Normal design review is absolutely fundamental in achieving high reliability. I don't have any question in my mind on that.

One needs a preferred parts list system so that the history of the components are available. These are the things that can kill you, if one doesn't know a change has been made in the way a transistor has been manufactured, you can't find out whether or not that is going to affect your particular application of it.

A great deal of work in what I call here "worker certification" is necessary. This involves all of the characteristics of motivation, training, education, and specifically certifying a person as capable of doing a particular job through a formal training, school, and a stamp which is kept valid. It is like a driver's license, only a little more severe. We use this now at our place for solderers, welders, for harness makers, and we expect to extend it to some other activities in the near future.

Formal failure analysis and feedback, of course, is fundamental, and a term that I call "tiger teams" is something which I think is extremely important, namely, a group of senior design engineers who can make last-minute reviews of the hardware, paper, procedures that are used in the launch operation in order to have a last-minute check to see that everything looks right.

That I think brings me out right when I am supposed to be through, so I will quit now.

MR. McKAY:

We will reconvene at 10:45 in the three work sessions of the morning.

The Management Review will meet in this Atlas Room, here.

The Human Factors in the Towne & Esquire Rooms.

The Supplier Coordination in the Sunset Room.

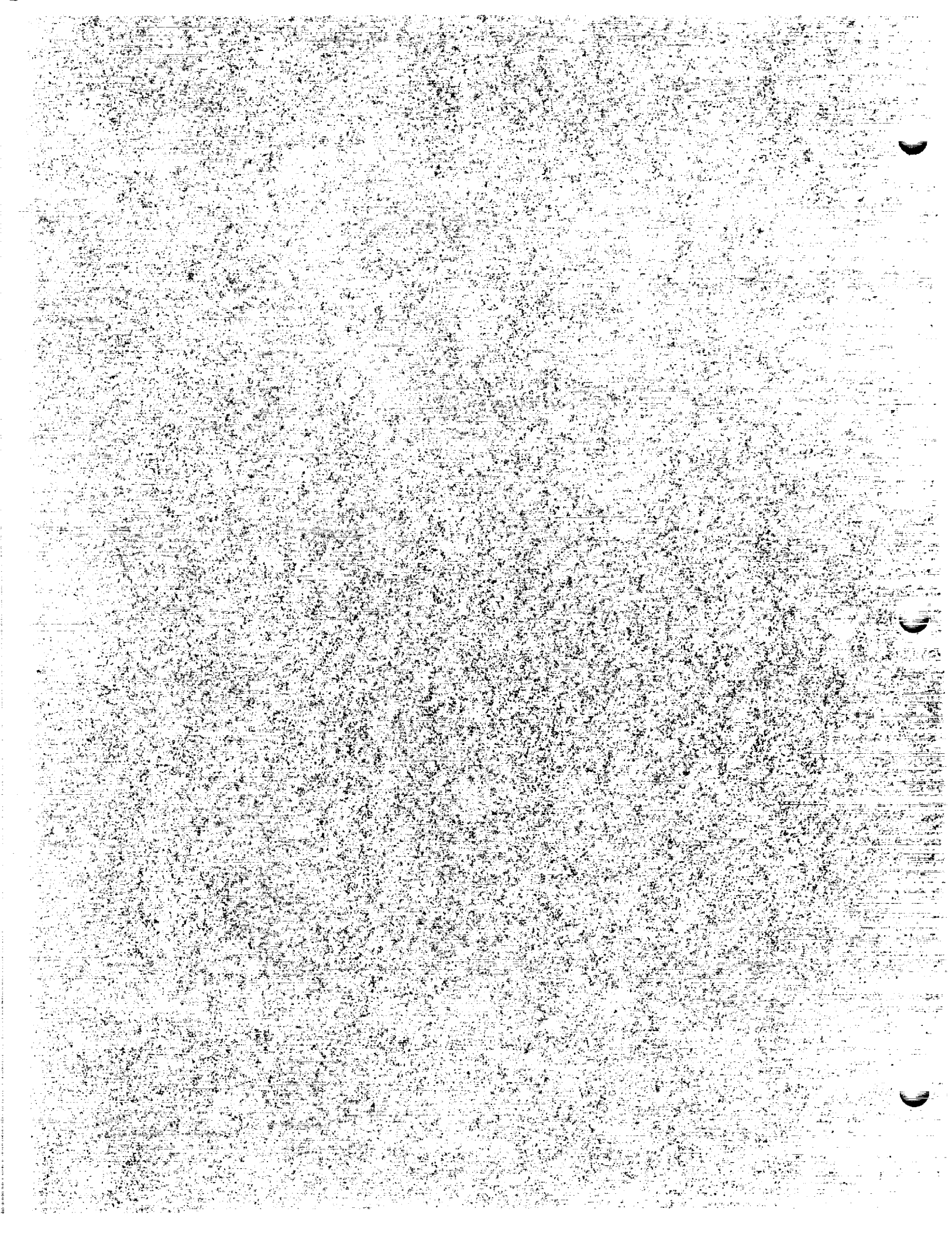
Subject Management Review

Time 10:45 to 12:00 noon

Location Atlas Room

This panel will review management of the Mercury-Atlas booster program, dealing with such factors as: the importance of a detailed program plan; recognition of management tradeoffs in the areas of reliability, cost, and schedules; organization for project management; program audit; and corrective action.
Panel members are:

Col. Robert Hoffman, USAF, Chairman
Mr. C. S. Ames, Astronautics, Coordinator
Mr. P. I. Harr, Astronautics, Coordinator
Mr. C. T. Newton, Astronautics, Coordinator
Mr. J. R. Dempsey, Astronautics
Maj. C. L. Gandy, USAF
Mr. B. Hohmann, Aerospace
Mr. J. McNamara, Rocketdyne
Mr. A. S. Torgeson, McDonnell
Mr. W. Williams, NASA



COLONEL HOFFMAN:

Gentlemen, I would like to first introduce the members of the panel whom you haven't been introduced to yet.

You know Walt Williams.

Major Toby Gandy is the second gentleman here. He has come from a background of flight test and at the present time he is the director of the Mercury Program at the Space Systems Division.

Next to Toby is Ben Hohmann, whom I mentioned before. He was the first test engineer to fly a rocket-powered aircraft. He is now with the Aerospace Corporation, the director of the manned space flight program.

You all know Mr. Dempsey.

Next to Mr. Dempsey is Mr. Joe McNamara. He is a typical major associate contractor, being vice president of the Liquid Rocket Division of Rocketdyne.

Then Mr. Torgeson, a representative of McDonnell Aircraft. He is the manager of quality control and reliability for the Space Flight Division.

These are the members of your panel, and I think to get the discussion started it might be a way to go to have each of the members just say a word or two and then we can open the meeting up to questions from the audience.

Walt.

MR. WILLIAMS:

Well, I have very little to add to what I have already said this morning. One point I would like to make though, that you heard three of us speak this morning about this program and this teamwork and this sort of thing. It is very easy to make speeches of that sort, which consist of a series of platitudes. I want to impress on everyone the fact that I think all three of us were sincere in what we said in this respect. All three speeches

were prepared completely independently, none of us knowing what the other was going to say until we heard it, and I think they told pretty much the same story.

I think in our discussions the thing that is most important in the management area is the people problem and motivation. Motivation in Mercury, I think, really, rather than decreasing with time actually increased with time, particularly up to the time of the John Glenn flight. I don't think it decreased after that. I think the edge was off a little, which was actually good. People didn't crank up quite so easily. But they knew, they had a certain assurance of what could be done, and this actually gave them confidence but not cockiness, inherent primarily to the launch crew in this confidence-versus-cockiness-type thing.

I am not sure in all of our programs, and even in our manned programs, we have the wherewithal to develop this motivation as easily, and I think this is going to be a very large problem facing all of us. I think in the manned program key mission, the lunar landing, it is very easy to build up motivation about such a mission. But I think the many missions that precede it and in programs that are not directly associated with it, such as Gemini, it is going to represent a real challenge to the total manned space management team to maintain the very high degree of motivation that did occur in Mercury.

COLONEL HOFFMAN:

Major Gandy.

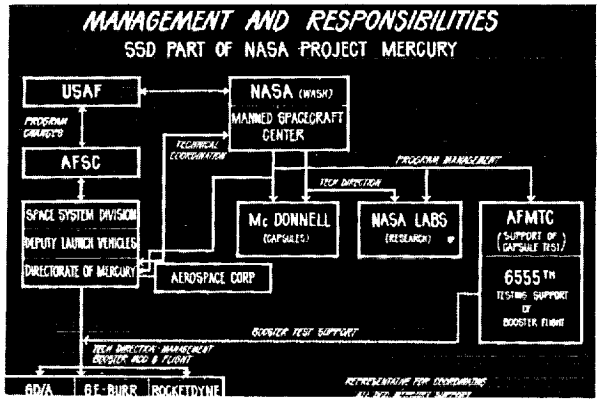
MAJOR GANDY:

I would like to point out a little, but, give you a hard frame of reference as to just where the Space Systems Division and the Air Force has stood organizationally in Mercury and to show you some of the tasks which we had to perform in carrying out our mission.

If I could have my first slide.

This thing is, as you can see, a rather complicated management structure, and really the only thing to save this from being snarled in a

spiderweb was this people-to-people approach that we came to develop. (Slide 1.)



Slide 1.

Essentially, starting from NASA's headquarters in Washington, requirements were placed on the Air Force, over here to Headquarters USAF, which were developed into a program, which was in turn given to Air Force Systems Command to carry out.

Systems Command then passed the program down to Space Systems Division, and the gentleman here is Colonel Hoffman, and down to our office, directorate of Mercury, which was the working level office to carry out the booster development and procurement cost.

Of course, parallel to us from the directorate of Mercury is Mr. Hohmann's Aerospace Program Office, which acted as our technical arm performing the systems engineering and technical direction job for us over this group of associate contractors.

You can see GD/A for the launch vehicle and the launch itself; GE-Burroughs for the guidance components and the in-flight guidance test, and then Rocketdyne of North American for the propulsion.

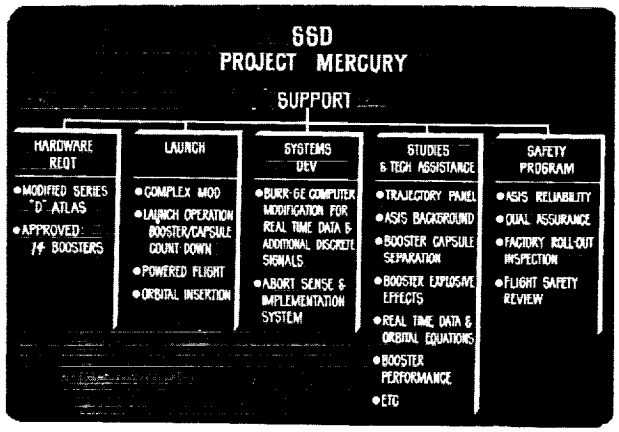
Now, on the other side of the house, from the manned spacecraft center there, McDonnell, the other NASA laboratories, which assisted in the program, and then on down through the national range support; then the actual launch agency -- I like to use the word "executive agent" -- was the 6555th Aerospace test wing. The launch director in the wing and myself here and Mr. Hohmann, of course, worked very closely together in establishing all the requirements, the launch documentation which controlled the actual conduct of the flight test.

This red line is the really important line in the program management. This is the line from Houston to Englewood, and this is the way that most of the program direction and coordination actually occurred.

Of course, we had to formalize through this channel in the long run, but on a daily basis this was the key communication link.

Next slide, please.

This slide shows the individual tasks which the Space Systems Division was called upon to perform in supporting the Mercury mission. First, of course, in the hardware department we were charged with procuring a modified Series D Atlas launch vehicle, and you will notice the change in the chart here. (Slide 2.)



Slide 2.

At one time this was 16; it dropped to 14 and finally ended up on the conclusion of the program as 10 individual boosters.

In the launch area we were responsible for modifications and updating of the launch complex, which was quite a major task in itself, and the booster was developed; similar changes had to be made, of course, in the launch complex.

The launch operation itself was our responsibility, actually performed by GD/A under the supervision of the Test Wing, and the countdown, furnishing the joint countdown was one task which GD/A performed for us under contract.

We had the responsibility for the powered flight up through the point of orbital insertion, at which time we packed up our bags and then sat back and enjoyed the rest of the mission.

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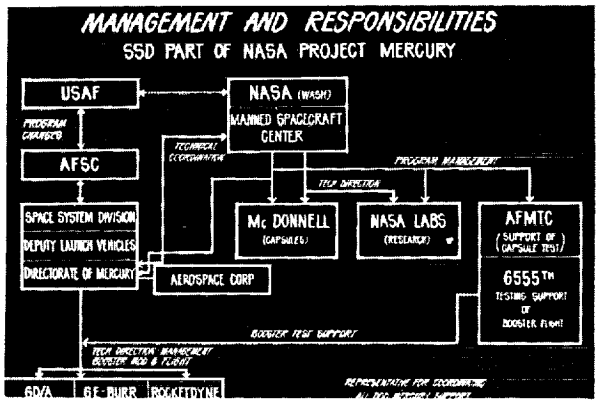

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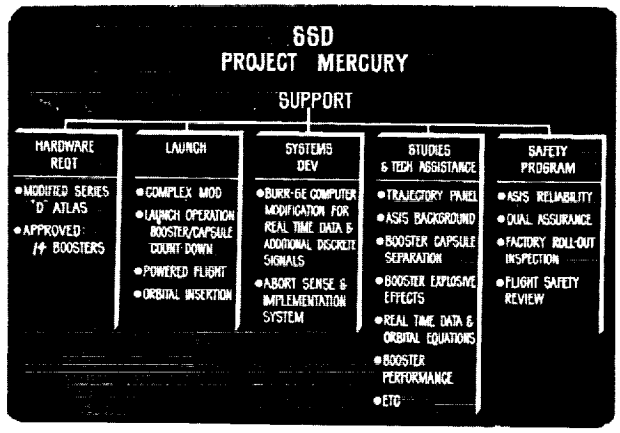

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We had, of course, a tremendous systems development job, such things as the GE-Burroughs computer radar interface, modifications to the standard guidance system to provide real-time data and certain additional discrete signals required in the Mercury mission, and the major system development which we undertook with GD/A was that of the abort sense and implementation system which fired the escape rockets in the event of a malfunction.

We performed, of course, leading up to the program and then later as the program progressed, a number of studies and technical assistance, such things as Mr. Williams mentioned earlier.

We had people from the O. B. & B. and later in the trajectory panel.

We ran a very extensive study of development of abort sensing system, studying all previous Atlas flights to determine what types of malfunctions could occur when in flight they occurred in order to develop the system to take care of these possible failures.

Another major effort was a study of the booster-capsule separation, not only the separation at the orbital injection site, but also the escape rocket.

There were, of course, studies on booster explosive effects, what kind of loads would you expect a capsule to take in the event of a catastrophe; would you actually expect a man to survive? This kind of thing.

Of course, real-time data and orbital equations were performed, considerable study performed by both STL and Aerospace for use in this area, and continuing studies on booster performance, such things as optimization of trajectories; this sort of thing continued throughout the program.

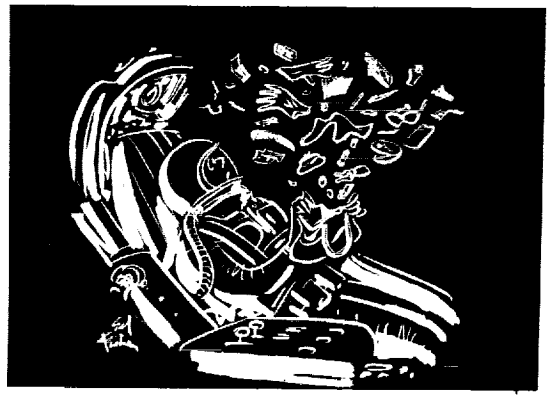
Finally, a major effort about which more will be said this morning was the pilot safety program, and this box should really be kind of like the Texan's concept of the United States. It should cover most of the chart with these others shoved over in the corner, because this safety program really pervaded everybody's actions at SSD. We were all completely involved.

I think the safety program took up about half of our time in any given working period, and Mr. Hohmann will cover this in a great deal more detail.

It is probably fortunate for us that the program had ended. I was just made aware of a new management problem, which is shown in the next slide. (Slide 3.)

We haven't had to cope with this one, fortunately.

Do you have anything to add?



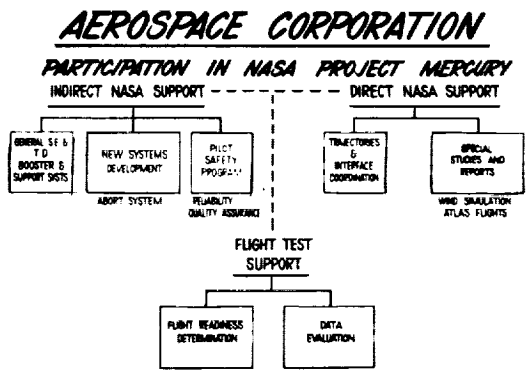
Slide 3

MR. HOHMANN:

Yes. I would like to talk a little bit about the pilot safety program, how it started, and what we learned from it. However, I would like to concentrate more on what we learned from it, and what we would recommend for future, more advanced manned-space programs.

In order to set the stage, I would like to show you one chart, how Aerospace Corporation saw their own effort in the participation of the Mercury Program. So may we have the first slide, please?

On Slide 1, you see three principal areas of effort. On your left is the indirect NASA support, which is guided in three areas, such as General Systems Engineer and Technical Direction, primarily concerned with the booster air support contractors or associate contractors.



Slide 1

We participated in new developments such as the abort sensing system, working out specifications, test procedures and objectives, and I would like to ignore the pilot safety program at the moment. I would like to come back to this last.

Going over to your right is the direct support of NASA. We at Aerospace worked out the trajectories and participated in interspace coordination and, of course, did special studies, such as, for example, to determine whether the upper atmosphere winds were low enough for the Atlas, with a special payload for which it was not originally assigned, to fly through.

We have then the flight test support area. In this particular area we participate in determining the technical flight readiness. This is a major effort, after the booster has gone through the factory, through the checkout at the Cape, and to determine the technical flight readiness, and after the flight we are participating in determining the flight test results, the flight test evaluations.

Let me go back then to the pilot safety program, which basically consists of three major phases: the basic booster reliability, quality assurance program with roll-out inspection, and flight safety review to determine the technical flight readiness.

This program started, as I recall, just about four years ago, when General Litton of NASA was quite concerned about the safety of the astronaut. Of course, we were also concerned. And in thinking about this, we have asked ourselves one vital question, one important question. This is shown on Slide 2.

How can we determine the flight readiness? After you have gone through all this, how can you tell that you are indeed ready to go?

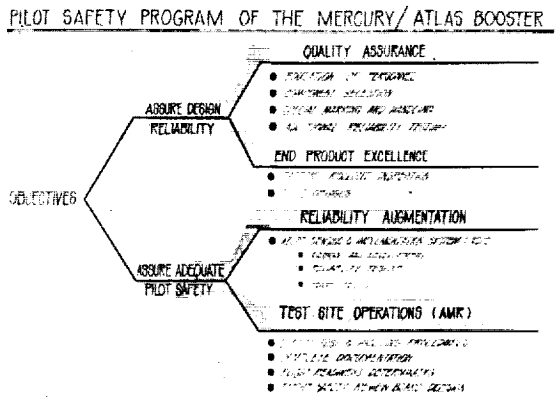
HOW IS FLIGHT READINESS
OF
MERCURY-ATLAS BOOSTERS
DETERMINED?

Slide 2

So we came up, at that time at STL, with a proposal which we then called the pilot safety program, and I would

like to point out here again, like many speakers did this morning, it was accomplished by teamwork between industry and Government. The pilot safety program cannot be accomplished by a single agency, single group. You first must establish a team to work with you, and the whole program is outlined in the one single slide in the next picture.

Slide 3 outlines here the major objectives of the pilot safety program. The first objective is to protect or assure the basic design reliability, which can be broken down in quality assurance, and I think Jim Dempsey covered this very adequately this morning.



Slide 3

I think maybe I should emphasize a little bit that an educational program was necessary by various contractors' and subcontractors' personnel to their factory engineering and inspection personnel to make everybody aware of the importance of the quality assurance, "Do good work." And before we take the liability, we want to make sure that it was complete, in one piece, that the systems worked together at the same time, simultaneously. We called this the rollout inspection or end-product excellence.

The other major effort on the part of the safety program we called the augmentation for pilot safety. This is to fill the gap between the basic reliability curve and the hundred per cent line. We all know that the Atlas was not designed originally to fly a man. It didn't have the experience as aircraft. We didn't even understand the environment in which the Atlas was to operate as well as an aircraft. So the sensing system was developed to fill the gap between the reliability and the one hundred per cent line.

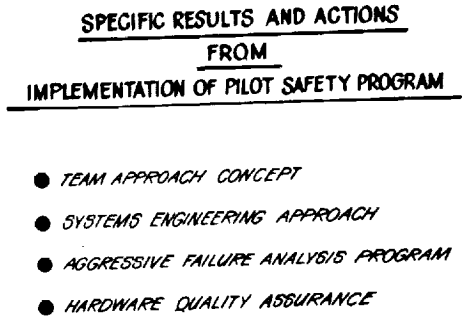
Finally we come down to the test site operations, which cover complete checkout, complete review and checkout and history of all changes, special tests, flyability tests, judge for critical weakness programs and so forth.

The important, final phase of this test site operation is the status review meeting, which determines actually the technical readiness, and which is then presented to our flight safety review board, and Walt Williams at NASA -- at which time the Air Force chairman normally recommends the booster for commitment for flight, or if additional work has to be done, this has to be accomplished too. This is the final decision when the booster will be permitted for flight.

I would like to point out there are a number of specialty teams, we had to set up teams consisting of representatives of Air Force quality control, Space Systems, Aerospace Corporation and other agencies, NASA, General Dynamics, to go through this in a great team effort. It has been very successful, and I would like to point out that it required the cooperation of many people, and I would like to just call out a few names, like Ernie Deutsch, who was with us from the early beginning, or Joe Randall or some other people.

I think they have all done a good job in addition to our staff at Cape Canaveral. So much for the pilot safety program.

I would like now to tell you what we think we learned from the pilot safety program, the four most important items which we learned. They are summarized in Slide 4.



Slide 4

This is the way we see this today. The most important thing we learned is that we must have a team-approach concept, that we should utilize or use the systems engineering approach, and no matter how embarrassing it may be, we should have an aggressive failure-anaysis program. If it doesn't work on the ground, fix it; it will never work in flight. And we have to have a hardware quality assurance program, which was already pointed out by Jim.

I would like now to tell you a little bit about future space programs, based on Mercury, and in the next slide -- I hope we are in the right order here -- we can set the stage for this.

About a year ago we started to write up our experience, and these slides were prepared for a different purpose, but they apply very well still today. About a year ago when we looked at this, we recognized a fairly large number of Atlas missiles had been flown, as a matter of fact, approximately 150 as of August of '62, and out of these 150, about 95 were of the D configuration, which is very similar to Mercury. (Slide 5.) It is not identically the same, but many, many components are used in the same environment and operated in the same manner.

If you will just make a mental note on these two numbers, 150 and 95, and then go to the next slide. (Slide 6.)

PILOT SAFETY FOR FUTURE MANNED PROGRAMS
(BASED ON MERCURY EXPERIENCE)

- MERCURY PROGRAM

  RELATIVELY LARGE NUMBER OF ATLAS FLIGHTS

  - *APPROX. 150 TOTAL ATLAS FLIGHTS (AUG 1962)*
  - *APPROX. 95 ATLAS "D" FLIGHTS OF SIMILAR CONFIG.*

Slide 5

I think we can all agree in making a couple of assumptions, like if we go to a new system, the increase in total complexity will be greater, such as in a design, in production, and in the mission. The increase in total program efforts also will be greater in cost, manpower, and time.

We will have less R&D support from other flight systems, such as weapon systems.

There may not, for example, be another Atlas weapon system where we could send components and systems on confidence flights as we had done on Mercury.

PILOT SAFETY FOR FUTURE MANNED PROGRAM (CONT'D)

- FUTURE ADVANCED BOOSTER SYSTEMS
  - *INCREASE IN TOTAL COMPLEXITY - DESIGN, PRODUCTION, MISSION*
  - *INCREASE IN TOTAL PROGRAM EFFORT - COST, MANPOWER, TIME*
  - *LESS R&D SUPPORT FROM OTHER FLIGHT SYSTEMS (WEAPONS SYSTEMS)*
  - *FEWER TOTAL PROTOTYPE FLIGHTS (UNMANNED)*
  - *LESS OPPORTUNITY TO DEVELOP AND MAINTAIN LAUNCH CREW PROFICIENCY*
  - *CANNOT ACHIEVE 100% RELIABILITY*

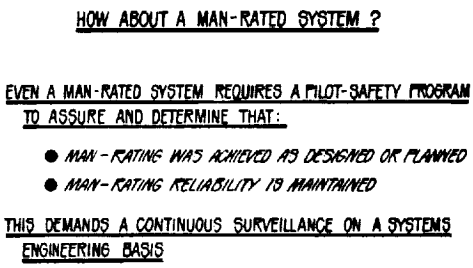
Slide 6

As Jim pointed out, I believe, we never had flown anything without having made confidence flights. We always wanted to have at least two or three successful confidence flights on a flight other than a manned flight, and, consequently, we will have fewer total prototype flights, unmanned flights.

If we have less flights we also have less opportunity to train and maintain launch crew proficiency. I don't believe that we can establish or can accomplish a hundred per cent reliability. So with this in mind, then, on Slide 7, one question appears logical:

How about a man-rated system?

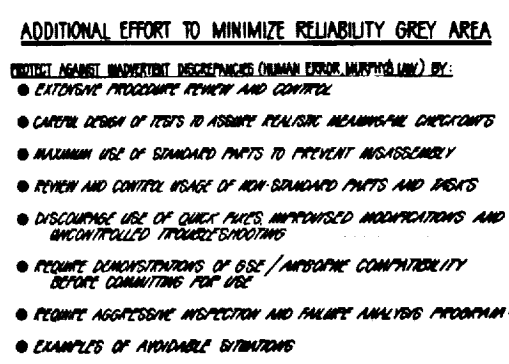
I think the term "man rating" is really a little bit misleading, but we think, even in a man-rated system, you need a pilot safety program which can be used as a management tool to determine or to assure that you have actually accomplished or achieved the manned rating as you had it planned.


HOW ABOUT A MAN-RATED SYSTEM ?
EVEN A MAN-RATED SYSTEM REQUIRES A PILOT-SAFETY PROGRAM TO ASSURE AND DETERMINE THAT:
● MAN-RATING WAS ACHIEVED AS DESIGNED OR PLANNED
● MAN-RATING RELIABILITY IS MAINTAINED
THIS DEMANDS A CONTINUOUS SURVEILLANCE ON A SYSTEMS ENGINEERING BASIS

Slide 7

Once you have it achieved, you maintain the manned rating. This is very important, because we found that any little change, tiny little change, can upset your whole reliability; as pointed out, sometimes a small component a manufacturer changes makes an internal change without changing a dash number, without changing a part number. No one knows that some day it will sneak in and may not work under all conditions, and this is precisely what has happened, as we all know. We think this demands a continuance of surveillance on a systems engineering basis where you continually look at all systems and make sure they all work with one another.

There is still one other aspect to it, which we will also look at on the next slide.


ADDITIONAL EFFORT TO MINIMIZE RELIABILITY GREY AREA
PROTECT AGAINST INADVERTENT DISCREPANCIES (HUMAN ERROR MURPHY'S LAW) BY:
● EXTENSIVE PROCEDURE REVIEW AND CONTROL
● CAREFUL DESIGN OF TESTS TO ASSURE REALISTIC MEANINGFUL CHECKOUTS
● MAXIMUM USE OF STANDARD PARTS TO PREVENT MISASSEMBLY
● REVIEW AND CONTROL USAGE OF NON-STANDARD PARTS AND TASKS
● DISCOURAGE USE OF QUICK FIXES, IMPROVISED MODIFICATIONS AND UNCONTROLLED TROUBLESHOOTING
● REQUIRE DEMONSTRATIONS OF GSE/AEROSPACE COMPATIBILITY BEFORE COMMITTING FOR USE
● REQUIRE AGGRESSIVE INSPECTION AND FAILURE ANALYSIS PROGRAM
● EXAMPLES OF AVOIDABLE SITUATIONS

Slide 8

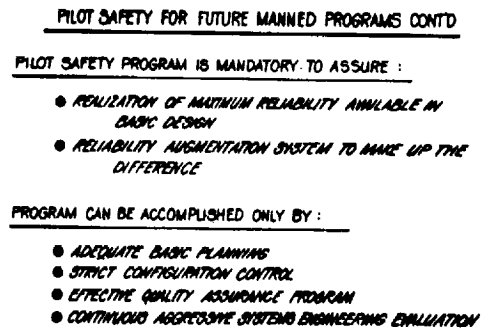
That is the human error part. (Slide 8.) I think if we could reduce the human error type or Murphy Law-type items we could actually improve the reliability somewhat. I think in order to control human errors we should address ourselves to extensiv procedures, review and control, to careful design of tests to assure that the tests are indeed meaningful, that a checkout really means something after you get through with it, that we have maximum use of standard parts.

We should also control the uses of non-standard parts. I think the next item is one of the most important items, discourage use of quick fixes or improvised modifications. We found that improvised modifications and uncontrolled troubleshooting can really get you in trouble. If you have difficulties in checkouts and something doesn't go right, the first thing you want to do, you want to stop. You want to stop the whole show and determine where you are, and if you don't have any controlled troubleshooting, then you will lose your base points which you may need in order to determine later on whether or not there was a redundant failure or it was indeed real. Many of these redundant failures were not redundant after all; they were real; they were there all the time. You had just not recognized them correctly.

We should demonstrate the capability of compatibility, and we should have aggressive inspection and a failure-analysis program as I already pointed out.

In Slide 9, we think, if you asked us, is a pilot safety program mandatory to assure the safety of the astronaut, we think it is absolutely necessary, even in a man-rated or even in future systems, which are more designed to carry through astronauts. We think you can use the management tool to assure the realization of maximum reliability, availability in a basic design, and that you indeed make sure that the reliability

augmentation, such as the abort sensing system, will be capable of making up the difference between a hundred per cent reliability.


PILOT SAFETY FOR FUTURE MANNED PROGRAMS CONT'D
PILOT SAFETY PROGRAM IS MANDATORY TO ASSURE :
• REALIZATION OF MAXIMUM RELIABILITY AVAILABLE IN BASIC DESIGN
• RELIABILITY AUGMENTATION SYSTEM TO MAKE UP THE DIFFERENCE
PROGRAM CAN BE ACCOMPLISHED ONLY BY :
• ADEQUATE BASIC PLANNING
• STRICT CONFIGURATION CONTROL
• EFFECTIVE QUALITY ASSURANCE PROGRAM
• CONTINUOUS AGGRESSIVE SYSTEMS ENGINEERING EVALUATION

Slide 9

We have listed here four items which we think should be considered in accomplishing this goal. Adequate basic planning, we should have a plan to work out the pilot safety program from the beginning. We should have strict configuration control and an effective quality assurance program, and a continuous and aggressive system of engineering evaluation at all times.

Thank you.

COLONEL HOFFMAN:

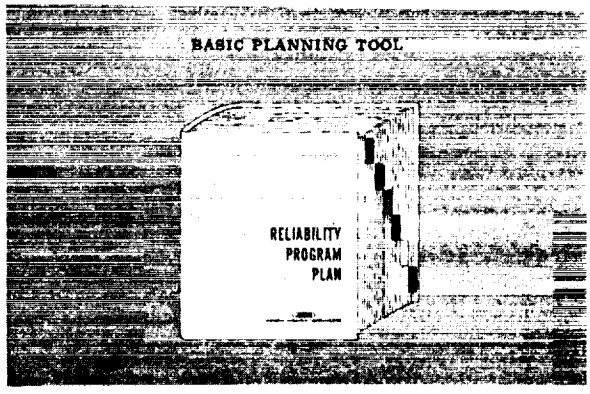
Jim, do you have anything to add to your previous comment?

MR. DEMPSEY:

I want to talk a minute about what I meant by top management attention, how we go about it.

All of us have mentioned the importance of a detailed work plan. (Slide 1.)

I have discussed the fact that at our place reliability encompasses a number of these characteristics of a system which, together with cost and schedule, really make up the considerations that a program manager has to be concerned with in his daily management decisions.



Slide 1

I have said that it is important to achieve reliability or to increase reliability, and I think Ben is right, to achieve a hundred per cent reliability is going to be extremely difficult, if not impossible.

If you want to achieve top management attention to this, about the only way I found to do it is to pay some attention to it myself, because, like they say, you say it but don't do it. Nobody believes really that you mean top management attention.

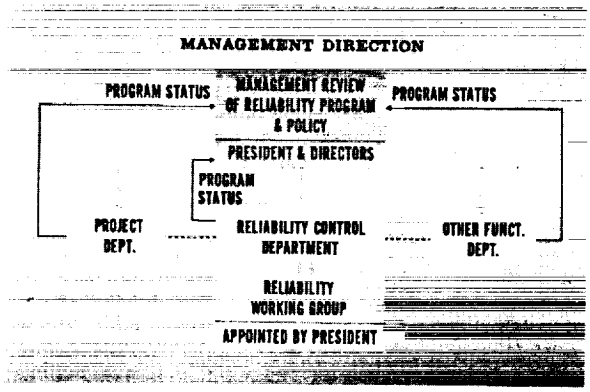
I will give you an indication of how in our organization the senior management works in respect to our reliability operations.

First of all, we consider that the reliability of our product is a line responsibility of all of the line managers. It is not a staff function and it is not something, as Walt says, that can be inspected into the product.

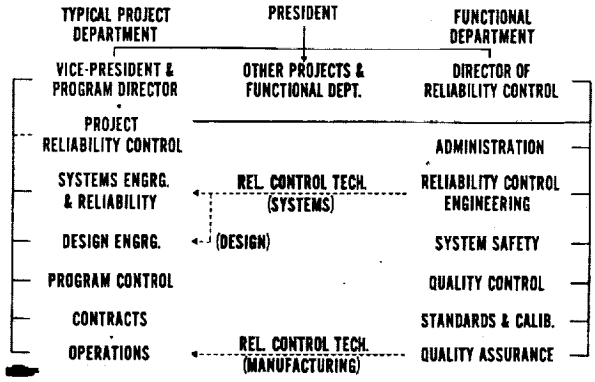
We have the organization, as I pointed out before, of four program directors and five functional department heads, engineering, operations, reliability control, and controller and administration, and a sixth one, advance product planning, which is really not concerned in our day-to-day operation.

So these nine people and myself are on the division staff, and we meet specifically once a month to review the status of the reliability programs in all of our projects. (Slide 2.)

The project vice-president is responsible for the reliability of his program, not the reliability control department. Reliability control department accomplishes certain activities in connection with this and is responsible to see that all the projects do things in essentially the same way or at least as appropriate to their projects.



Slide 2



Slide 3

On the left side of Slide 3 you will see the typical project department organization, headed by a vice-president and having line functions of system engineering and reliability, meaning the engineering reliability of the product, design engineering, program control, contracts, and operations. He has as well budgeting and estimating responsibilities for the project. So he has all those functions which are necessary to do the job. He has the authority as well as the responsibility, and he has a project reliability control group, which is actually part of the line element of reliability control, but is physically located in the project area and acts as a member of the project director's staff. So that in this way I have what might be called a direct reliability control checking system on everything that goes on in the place.

The reliability control department, which you see on the right, in addition to the project groups which are located in and perform these functions for the projects, has a reliability control engineering function, system safety, quality control, standards and calibrations laboratory for the entire division, and quality assurance, and performs in respect to all projects the establishment of standards or ways of doing business fundamentally, and a followup to see that these are accomplished correctly.

I have come to believe that only by this kind of an organization and by this kind of attention on a regular basis will people really believe that we are paying top management attention to reliability. And by "people" I mean those people in our organization, not those in other organizations. It is the people in your own organization that have to be convinced, really.

I have mentioned this list of lessons we think we have learned this morning. (Slide 4.) I think we can skip those now.

COLONEL HOFFMAN:

Mr. McNamara, do you have comments?

MR. McNAMARA:

I think maybe a few.

HOW TO INCREASE RELIABILITY

- AGREEMENT ON NATURE OF PROGRAM
- TOP MANAGEMENT ATTENTION
- DETAILED WORK PLAN
- FORMAL DESIGN REVIEW
- PREFERRED PARTS LIST
- WORKER CERTIFICATION
- FORMAL FAILURE ANALYSIS & FEEDBACK
- TIGER TEAMS

Slide 4

I think they may be relevant to this meeting. Of course, at the risk of being a little redundant, I would again like to point out that our experience in this program, in the cooperation and the team effort that we have participated in, has been of considerable importance. This program naturally has had its problems, its failures, and its disappointments; but our experience has been that when these do come about, this group works together, the problem gets rapid attention, and a solution is reached rather rapidly. This is going to be a continuing program. The interface among all of the agencies, and as these programs move on they become more complex, will tend to make this even more critical.

As far as our program is concerned, we have applied the propulsion system. The propulsion system in the space launch vehicle grew out of the Atlas Series D. It was our MA-2 engine; at the time the Air Force selected this engine, which was late in 1958, this engine system had a nominal reliability of 84 per cent. Today it has a nominal reliability of 98 per cent. We have been fortunate; we have had other similar engine systems, such as the Atlas MA-3, the Thor, the Jupiter, and ASIS A-1 engine, that have helped support and develop this entire system. As a matter of fact, to date we have had over 2,300 engines in this category that have been test-fired for something over 1,100,000 seconds and have launched about 427 birds. I think this has been a tremendous advantage to us. It has allowed us to develop the confidence that we need and to keep this thing moving.

Now, the engine system supporting this space vehicle is known as the MA-5. The R&D has been completed on this engine. Right now we only have some maintenance engineering, a very low production rate. I think

this problem -- I don't think is peculiar to us -- presents a problem to management, to the organization, in which we now have to maintain and maybe continue to improve this reliability, raise it, and maintain interest in this whole program.

The programs have been stretched out. We find that we have the usual problems with vendors and suppliers, and we must pay tremendous attention to the details of a program like this, this particular program with a fixed price contract, and I was particularly interested in Jim's RCS triangle this morning, because here is a program that is a low-rate program, a fixed price contract, and it is in an overrun condition. A lot of people know what this word means.

We have been able to isolate part of the cause of this to a particular hardware program, but a good hunk of this thing is due to the increasing requirements for quality and reliability. We are all pushing towards this direction. The whole country is directing this thing, and when you get a contract such as this, it runs for three years, suddenly you find out that your programs are going to cost you more. I think this is a problem we have all got.

I think that is all I have to say.

COLONEL HOFFMAN:

Mr. Torgeson.

MR. TORGESON:

Yes, I have a few. The comments made by the people preceding me here have hit on a good many of the points that I would like to make. However, I think I can provide some useful input in indicating how I feel about these various factors, and how they are treated, can be used to improve the efficiency of reliability program management.

What I would like to see -- and I think this eventually is inevitable, but feel it should be deliberate -- is a planned program for integrating reliability quickly into the basic functions rather than to allow huge parallel organizations, but which are outside the line organization of the operating organizations, such as the design, the test and development, and some manufacturing and procurement activities.

The reason I say this is illustrated by the fact that has been mentioned many times here, that there must be the motivation on the part of everybody to do good work or, as one comment I heard in the audience this morning, it must be almost an emotional thing with the people on the program.

Well, the only way you can make this fully effective -- I wouldn't say the only way, but I believe the most efficient way that you can make this fully effective -- is to both motivate and equip the people to apply their motivation effectively, who are doing the design work, who are doing the test work, who are doing the procurement, rather than, let's say, allow the feeling to develop that, well, there is another organization that has the responsibility for reliability, and, therefore, I can worry about other things.

This I think is well illustrated by the comment that you cannot inject reliability into something that has been designed or developed. It has got to be obviously a part of that design.

I don't mean to say by this that you wouldn't have reliability organizations, and I don't mean to criticize either the government agencies or the industry, my own company or any others, for past and present efforts; I think, for the simple reason that reliability has a specialized function, it is relatively new in this industry. Until it has found its proper place, such as the art of the structural analysis has through years of long standing, that special emphasis and special organization alignment with, let's say, direct approach to the top management have been necessary.

I believe that as the art has found its proper position that it can properly level off at a situation where all of the people in the line organizations, the design people, the test people, procurement people, and all the manufacturing people, both recognize their responsibility for reliability in their work and have the basic tools that they need to accomplish this.

Then the specialized work such as reliability planning, the basic analysis, etc., of course, must continue to be done, or I say can most effectively continue to be done by specialized reliability engineering organization.

Now, a few comments on how this can be accomplished:

One, of course, is motivation and training for all levels of management and workers.

We have done this to a reasonable extent for the Gemini program at McDonnell, and I think this kind of effort must be continued and amplified and improved as time goes on. Along with form and training classes, of course, are motivation through examples set by the management. In other words, when the chips are down, management illustrates by its action that it really means to have reliability in the product, and this can filter down to the working level much more effectively than any pressure from an outside organization, which can be, after much effort, easily undercut by a simple decision, which would illustrate that some level of management is not backing this program.

One means of getting both the motivation and the capacity into such people as the design and test engineers -- and I emphasize those not because reliability ends with design or testing, but the biggest payoff is in the design and development test phase. That means the deliberate cycling of personnel through reliability engineering groups and then back to the original design or test groups. Some of this, of course, happens everywhere. It has in our organization, just through natural events. People are transferred and so forth.

But I find that it does have a healthful effect where there has been some reluctance on the part of design people to accept the usefulness of inputs reliability people can give them. This has improved when some ex-reliability engineer joins their group, for instance.

This, I guess, is a good bit of repetition, but as Mr. Hoffman mentioned, the reliability can only get into the product by good basic design, and the only people who can effectively do this are the people who are doing the design rather than have it done without proper consideration, and then the attempt to upgrade that through the input of some outside organization.

The good design of tests, which again can most effectively be done by the people who are going to conduct the test; the use of the most reliable, available parts -- I have found that it is sometimes quite difficult to get

appreciation, sometimes even among experienced designers, but particularly among procurement people, of the need to buy parts which you know are the most reliable, and available, even at the expense of higher cost and various other disadvantages.

I don't think you will accomplish the best results in this area until you have the procurement people themselves so reliability-oriented that they do this automatically.

A point that has been brought up here several times again is the need during testing or flight operations for complete and accurate fault isolation and troubleshooting investigation when some anomaly occurs. I don't think I need to stress the importance of that any more than has been done, but here again the way to get this done most effectively is to get that appreciation and that capacity -- the special ability, and I should say inquisitive nature that it requires, into the test engineer rather than, let's say, to retain it in an outside organization.

I believe since so many of these points have been covered previously this morning that that is about sufficient.

COLONEL HOFFMAN:

I am sure that with all these items that have been discussed some questions have generated in some of the minds of the people, and we will certainly do our best to answer any questions that you may have.

Are there any questions?

DR. BALL:

I would like to ask Mr. Dempsey if there are any keystones that he might mention as to how this proper management interest was communicated to the troops, and was there any feedback system to insure that this communication was getting through?

MR. DEMPSEY:

Yes. There is a great deal of discussion on this going on now in the Human Factors Panel, where they are describing the programs we had

for employee training, motivation, identification with the program, and things of that sort. All of these things took place in a formal way.

We made a movie and showed all of our people who worked on the Mercury, as well as all of our suppliers who were furnishing critical components.

Another thing, as has been pointed out, which I think was very valuable, was the time that the astronauts themselves spent in the factory talking to the people on the line. We got out ourselves and walked in the factory.

I get out in the factory every week and walk around and talk to people and look at them, and at least they know what I look like out there. I think this is important. I do this as well as the senior staff people. I think it is fundamental.

These are all fairly straightforward indications of recognizing the people as people and giving them recognition. It is just a little matter of discipline to force yourself to do it.

COLONEL HOFFMAN:

I think one other indication that I have run across in another program, on a rather limited scale, when you can identify the workman and somehow or other in his production identify this individual.

In the sample that I looked at, there was a noted increase in the number of items that were accepted, so that a man got the word, he was able to write his name on the piece of material that he was working with, and then people knew that he had produced it. So getting this individual's name on it helped in that instance.

MR. DEMPSEY:

That is a very good point, and that is something that we do, particularly in areas where Walt was talking about, where one workman solders a few valves and pin connections, that person knows that his work can be identified back to him as an individual.

MR. McNAMARA:

It is real interesting that on defective workmanship, I think we are all working pretty hard on this one, we are after the guy that is doing this. This may represent five per cent of all the parts, but the other 95 per cent that is done good and well, somehow we just don't get that to the people, and to give them the compliment and the confidence that they need.

MR. DEMPSEY:

Something we are doing now came out of this same idea, which is discovering one day that the only guy who got any attention was the guy who busted something.

We had a campaign on material handling, and so the only people who got their pictures on posters were those who just dropped a gyro or something.

(Laughter.)

So now we have a program under way to rate departments rather than individuals, starting with departmental groups, on the quality of the workmanship, and one of the things we are going to do is give the winning department a dinner or something like that, this kind of campaign, to recognize good workmanship, as Joe points out -- because we already had a lot of it -- what we are trying to do is get that last five per cent.

COLONEL HOFFMAN:

This calls to mind one other example. In our new cost incentive contracting one of the companies has identified the particular element of the incentive to a particular job, so that the guy who is building this knows that if he meets that incentive then the company gains another few dollars on their product.

So here is another way that you might put this over.

DR. BALL:

I would like a definition of the term "program management technology" and then address a question to the panel: Define this as a system for insuring that knowledge gained from previous experience is applied to new programs, to the maximum degree possible within limits of cost and schedule. Of course, today this is a reliability work shop. So we are particularly concerned with preventing reoccurrence of the problems.

This is the question: Is this program management technology becoming a reputable reality, and if so can it be formalized and taught?

MAJOR GANDY:

I would like to take a crack at that. Yes, I think it is becoming recognized as a field, and certainly the Air Force is beginning to teach it. We have had a course running at the Institute of Technology at Wright-Patterson on a system program management. The length of course is varying and this sort of thing, but they are taking people from program offices, running them back there from, I might say, quite diverse program offices and quite diverse backgrounds, and running them through a course where they are exposed to successful program managers. This is one of General Schriever's projects. He himself kicked the thing off and has spoken to each class so far. He has had many senior project people come back and talk to these students, in addition to their normal, what you might consider normal, instruction in contractural matters and this sort of thing, the working knowledge they have to have anyway. So I would say yes. It is being recognized, at least, in the Air Force, and I think the industry, of course, is doing a lot of similar things. I think the academic people are also coming up with similar courses in the university.

COLONEL HOFFMAN:

I think it has not been recognized only but being demonstrated. In Titan III, I think we can say at this point in time we have been able to define that system much more accurately than we were back in the days when Jim Dempsey started working on the Atlas; not only have we been able to define it, we have been able to go out on definitive contract with the incentive clauses tied to a particular element of it. You could just see this

thing falling into place so much more clearly than you could back in the early days, so I think significant progress is being made. Of course, the proof will be in the flying of the bird.

VOICE:

I noted in Mr. McNamara's talk the MA-2 booster was boosted in reliability from 84 per cent to 98 per cent. I was wondering if there was any special procedure that you developed during the process of this reliability improvement.

MR. McNAMARA:

Certainly, there have been improvements made, particularly in this engine. There have been failures due maybe to pump rubbing that has caused explosions. We put, in the pump to reduce this, baffles in our injectors to reduce instability or to eliminate instability. We now got what we will consider a dynamically stable injector. If something causes this thing to go off, it will recover within a matter of milliseconds, ten, twelve.

But more particularly in this cost picture, our quality control has certainly been tightened down, starting with the vendor or receiving inspection, and all the way through; we have a very heavy quality assurance plan. We have a quality control plan for each critical item, an inspection plan. This is something that has come into being in the last couple of years. In spite of the fact that the costs are going up, we say the quality is better and the reliability is up.

There has been a lot of management attention -- we have a reliability board. We feel this has got to be done in the line. We do try to measure the performance of our shops and the output.

COLONEL HOFFMAN:

If I can just add a word to that, so I don't miss the opportunity: It is my impression that those millions of hours of runs, engine runs that Joe has made, have been effectively analyzed so that the information could be fed back in so that they weren't just running to be running.

MR DEMPSEY:

Failure analysis.

COLONEL HOFFMAN:

Are there any other questions?

VOICE:

When you take a look in the literature you find to a large extent you get caught up in some abstractions. Now, would the panel care to comment on the top link of these triangles?

MR. DEMPSEY:

Yes. First of all, for example, schedule: When schedule is more important than anything else, one undertakes to parallel solutions to any problem, which seems to be uncertain, or where there is any degree of uncertainty. We went through, for example, the development of something like four boil-off valves on the Atlas before we got one which we finally stabilized. We developed three or four pneumatic regulators and things of that sort. If cost were more important, one wouldn't do that. One would undertake the development of one and let everything else wait until that were working.

So I think that there is quite clearly an indication that, where schedule is most important, that one makes sure that there is a solution to every problem, and this is therefore more expensive.

When reliability becomes more important, then one is prepared to wait and to spend money, and this normally means additional testing in order to be sure that the performance is as one has calculated, and this involves a very much greater expense in the testing part of a program and the record-keeping of component records -- I think the Minuteman component reliability program is a good example of that, and in general the attention that one gives to being sure that everything is working just right and that one can explain all the anomalies, I think this shows up in the cost directly.

We have accumulated about twice as many factory hours on the Mercury birds as we have on the average weapons system bird, and just to show you that Joe's remark is right about the changing standards of quality and what we now consider to be good quality, we are now spending on the average of about 30 per cent more hours on all of the space launch boosters that we make now than we did on the weapon system birds a year ago. So we are definitely in the whole industry, industry and customer combined, upgrading our ideas of what are acceptable qualities, and this costs more money.

MR. WILLIAMS:

I would like to add a little to that. I will take the other side of the coin a little bit in that a highly reliable article, talking in terms of a complete development program, spending time in the reliability area or dependent area does not necessarily cost more, nor does it necessarily delay the schedule. This is because the cost of failure and the schedule impact of failure, particularly in a program such as we have been running, is so very high.

The two failures we did have, I think, in time cost us approximately six months each. I think this has been true; I think if you analyze many of the airplane flight test development programs, the major accidents, particularly if it involved a fatality, cost in time four to six months. This seems to be a little hard to get around this one.

Of course, if it costs time on the schedule, it costs dollars, also. So balancing these out becomes very much, I think, an intuitive sort of thing.

MR. DEMPSEY:

It is important to notice in the case of a weapon system one is normally interested in the statistical reliability of a large group of things whereas in this case we are interested in the highest possible single reliability.

MR. WILLIAMS:

That is right. That is the reason I related it also to the aircraft rather than ballistic missile, in that, where lives are involved, the approach is different.

COLONEL HOFFMAN:

In some of the payloads they cost in order of magnitude more than the booster system, for example, so you can see that a little more time and a little more effort spent on the booster will pay off many fold in saving the payload that you are putting into space.

MR. DEMPSEY:

I would like to add one comment to address a question that Dr. Ball raised about whether program management, or program management technology is something that can be taught. I think it is certainly true, as Toby pointed out, that it is possible to teach what the successful elements or program management are, what the elements are that compose program management, but now in teaching it it becomes difficult because human relations are involved, and like anybody who has a teen-age daughter knows, it pretty hard to transfer your experience from one person to another.

It is also true, I think, that what the characteristics are of a successful program manager defy codification because in nearly all studies of the elements of success the only common factor to these people is that they are successful. So I do think you can teach what one has to consider, but because so much of program management involves interpersonal relationships with subordinates, with peers, with bosses, I think it is going to be very difficult to say you can take a person and make him a successful program manager.

DR. BALL:

The panel I see has used the term "reliability specialist" several times. I would like to offer a definition of this and then ask their comment. Reliability specialist is an engineer who can analyze equipment failures and, in terms of technical and management action, control their recurrence.

Is this ability to analyze the principal element that distinguishes reliability specialist from, say, a design engineer, inspector, or a program manager?

VOICE:

Are these Dr. Ball's definitions or some other?

DR. BALL:

These are spur of the moment.

VOICE:

Is this failure before it happens or after it happens?

DR. BALL:

This is the analysis of problems as they happen. Several times on the slides here we have had emphasis on what was called agressive failure analysis, and presumably it takes a specialist to handle this, what the panelists have regarded as a key function.

MR. DEMPSEY:

I don't agree with that.

VOICE:

I think time is important.

MR. DEMPSEY:

I think the ability to analyze is almost fundamental to anybody who wants to be connected with any part of our business. Maybe I am interpreting your definition too literally.

MR. WILLIAMS:

I think there is another thing to it too:

I think the designer, the design engineer working on a system primarily looks at how it will work, how it works. Your reliability man or your flight safety man perhaps looks at how the system won't work and the implications of this.

MR. DEMPSEY:

That is the one of the principal functions of the formal design review, to bring to bear the specific design experience of other people and to consider how are the ways it can fail.

MR. WILLIAMS:

Yes.

COLONEL HOFFMAN:

Jim, how is the scheduling? We are running a little bit past our time.

MR. DEMPSEY:

We are five minutes late right now, I think.

COLONEL HOFFMAN:

If there are no other questions, I understand lunch is being served out on the patio.

(Whereupon, at 12:00 noon, the panel was concluded.)

Subject Human Factors

Time 10:45 to 12:00 noon

Location Towne and Esquire Room

This panel, in discussing human factors, will focus on motivation of personnel in the program. Specifically considered will be areas such as reliability, subcontractor programs, visual devices, training philosophy, and Air Force and NASA coordination. Panel members are:

Lt. Col. R. H. Brundin, USAF, Chairman
Mr. R. Evans, Astronautics, Coordinator
Mr. J. Croft, Astronautics
Mr. V. Heger, Astronautics
Mr. F. Johnson, AiResearch
Mr. R. Keehn, Astronautics
Dr. D. Meister, Astronautics
Lt. Col. P. W. Richardson, USAF
Mr. R. Rovenger, NASA

MR. EVANS:

Gentlemen, my name is Ross Evans. I am with General Dynamics/ Astronautics as manager of personnel administration.

I have the honor of introducing your panel. I think the first thing that any group wants to know when they listen to something in any subject area is, what are the backgrounds and what are the qualifications of the people they are going to listen to.

Now, first, I would like to introduce Colonel Bob Brundin on my left (indicating), who is your panel chairman from the Air Force. We are delighted to have him; we are fortunate to have him.

I asked Phil Culbertson and other Astro people how to introduce him and they said, "Just introduce him as one of the Air Force people most instrumental in some of the things that were talked about in the management session this morning."

He is now deputy head of the Chemistry Department at the Air Force Academy and since he was in the Mercury Program at the time the emblem was construed or constructed, I assume that his background as a chemist had something to do with the acceptance of this emblem for the Mercury Program.

At the time of the program he was the Director for SSD of Missile Launch Vehicles.

Now, so much for the chairman. He will be taking over in a few minutes after I get through with the mechanics.

I would like to now introduce the rest of the panel. We have on our far right Mr. Dick Keehn, who represents Astronautics as far as the Mercury is concerned. He was in charge of checkout of the Mercury Program until '61, and then he was assigned as assistant program director of Mercury, and now is with the Space Launch Vehicle (SLV) Project.

He is a product of one of the policies of Astronautics. He is an engineer who started out in the production area, and I am sure got a very fine background, and has risen rapidly in our organization.

Next to him we have Dr. Meister from the Reliability Department. He came to us from the American Institute of Research in Pittsburgh. He was in charge of Human Engineering for Atlas Reliability Department; is now in charge of human factors and maintainability in the SLV Program.

Next is Jack Croft, who at the time of the Mercury Program was a supervisor in professional and technical training, and now is the chief of educational services, in charge of all educational programs for Astronautics.

On Colonel Brundin's immediate left is Frank Johnson, who was kind enough to come to us from AiResearch Corporation in Phoenix. Frank represents a major subcontractor, and is an example of how this human motivation program was carried from the integrating contractor down to one subcontractor.

Certainly there are many other subcontractors involved, but I think Frank will show us how they used these principles.

We have next Vern Heger. Vern Heger is responsible for the various placards you see on the areas in this room and the other, and visual aids.

He is the director of Internal Communications for Astronautics. He tries to see that what we print and what we put on movies and other graphics all dovetail and tie together.

On his left we have Lt. Col. Richardson. Colonel Richardson was a project officer in the Air Force Project Representative's Office at Astronautics during the Mercury Program. He is now busying himself with the Space Launch Vehicle Program.

Last, we have Ron Rovenger who is now assistant project manager for Centaur and is the senior NASA representative at our institution. He came to us from Huntsville where he was on the Saturn Program and the Jupiter Program and previously on the Nike Program.

I almost feel like introducing three ghosts here, namely, Colonel Hoffman, Walt Williams, and Jim Dempsey, because I think they've got us off to a very good start on our particular program.

In fact, I didn't realize quite that we were so important, but certainly I think the fact that discussions of personnel and human motivation occupied a great deal of their time, it is worthy of us to try to then carry the next step forward in this particular discussion of just exactly how did they do it.

Now I prepared a 15-minute introduction that I was going to give before we knew Colonel Brundin would be here. I gave him the 15-minute introduction and said, "Well, just incidentally, we have a little film clip. Would you like to see that and then you can decide afterwards which one you want to introduce the program with?"

And he listened to my introduction and saw the film clip and we are going to see the film clip first.

(Whereupon, the movie "Locked On" was shown to the members of the panel.)

MR. EVANS: What you have seen are just three little excerpts from some of our visual productions.

Since we do have a celebrity in the room, I would like to introduce him to you. I can't introduce General Estes, but I would like to introduce Joe Moore.

Joe Moore was one of the actors in the film. He received the award in the last film clip and I think he deserves a hand.

(Applause.)

MR. EVANS: We presented a group award and he was the representative of the production department who received it from the Air Force Command.

I would like to just quickly comment on the film. You will note in all cases except for General Estes we used actual employees. Secondly, of course, the only other non-employee, if you saw the rest of the film, would be an astronaut.

I am now finished with my job until the question period. I am proud to turn this meeting over to Colonel Brundin.

COLONEL BRUNDIN:

Thank you very much, Ross.

I think even though these film clips are a bit out of context, they come from separate film coverages, both Ross and I felt that they defined the scope of our panel perhaps better than any one of us could, perhaps even with the help of Webster.

This honest, very honest motivation was, what was the task that we set ourselves out to do very early in the Mercury Program.

Our subject, of course, is human factors and this is a very broad one. As pointed out in the program, we are dealing on the matter of personnel motivation.

Now the source of personnel motivation has to be from the top. I think this was brought out quite clearly by all of the introductory speakers this morning.

You have heard terms from Walt Williams, such as integration and unification, and I believe there was another one added, teamwork. There was a very honest belief in this program by all of the people who began with it, and this generated out throughout the structures of the organizations involved.

There is one significant event, however, that I think important to mention in the way of the development of the motivation aspect of the program, and for this purpose I would like to refer to our commanding general at the time at, then, Ballistic Missile Division, General Ritland.

I had just come on the program in August of 1959 and one of the first pieces of paper that I saw was a letter which General Ritland wrote himself and sent down to my program office.

Basically, what he asked us to do was to devise a program which would make sure that no stone was left unturned in the matter of assuring the safety of the astronaut. The object was to arrive at, the day before John Glenn's flight, the feeling that we had done everything conceivably possible to assure his safety.

Out of this grew the pilot safety program, quality assurance program, which has been referred to earlier this morning, and as part of this quality assurance program, the matter of personnel motivation played a tremendous role.

This panel has discussed the subject considerably. We will be starting with a three to four-minute talk by each of the members of the panel, not so much to cover the field, but rather to give you an overview, to find the scope, and perhaps stimulate some questions.

This panel, we hope, will be your panel as much as it is our panel.

Leading the discussion will be Dick Keehn, who will be followed by General Dynamics' employees and our representative from AiResearch, and finally by Colonel Richardson representing the Air Force on the scene in the plant at San Diego.

We hope that this defines the scope for you, and once again, I hope you will once again feel perfectly free to participate in the discussion which follows.

Dick.

MR. KEEHN:

Thank you, Bob.

The problem of motivation of personnel is an old one. It is particularly important when dealing with the complex machine and the missile or launch vehicle or booster that was being prepared for Mercury use as a complex machine.

It is complex to build; it is complex to test; and it is complicated to operate. All of these complexities are, as far as the launch vehicle is concerned, reasonably predictable. They are based on fairly-well defined scientific and engineering formulae that allow those trained in the field to predict what is going to happen under certain conditions.

The factor that is unknown and in spite of the fact that psychologists can predict the behavior of the human under certain conditions, the fact

that human beings are the important ingredient or the irreplaceable ingredient in the performance of the buildup, the test, and operation of this vehicle, and these human beings are also complex machines, but they are not nearly as predictable.

In our preparation for our work on the Mercury Program it was necessary for us to recognize this, of course, and take steps that would allow us to be in a better position to predict the performance of each of these people.

The word "teamwork" has been used this morning I believe by each speaker, that is the talks so far, and I am sure it will be carried through the entire day.

To be a little more specific, the people that we used, the teams that we created began in the factory. The teams initially were made up of those people who had, in our estimation, the most experience and the best abilities to perform their tasks as it pertained to the Atlas.

Joe Moore, who you just met, was one of the first supervisors of the Mercury test team in the factory.

We chose to identify these people with special badges as a mark of distinction for them and also as a mark of identification for those who managed the operation, to insure themselves that only those people who were on this authorized team would actually do work on the Mercury boosters.

It soon became quite a badge of honor to wear this special Mercury badge beneath their regular badge. There was a lot of active competition among the other checkout crews for any position that may have become open within one of these formalized crews through normal employment attrition.

This was found to be extremely healthy. We felt it generated and encouraged the team spirit throughout.

The teamwork was followed on through to the site, as was pointed out in Mr. Dempsey's talk this morning, and also by Walt Williams. The

launch operation crew was a select crew and it was maintained in its configuration without replacement of personnel, as near as is possible in this type of business.

An interesting thing may be pointed out in this area, during about halfway through our task in checking out the Mercury boosters in the factory, the base activation activities, which we were deeply involved with at that time, began to taper off. This resulted in several people with similar job descriptions being made available, many of whom had greater seniority than those that were on our checkout teams in the factory. These people then had the right to come back into the factory and replace these employees, based on their seniority.

After evaluating this situation carefully, we in management approached the union, and this is something extremely unusual we feel, and pointed out the problems that we felt we were faced with and actually got union concurrence to deviate from seniority replacement of people so that we would be able to maintain our Mercury teams intact, and this merely points out the effective motivation, not only on our employees, the actual people doing the work on the line, the managers and supervision on the line and throughout the division, but it was also reflected into other organizations that dealt with us only on a fringe basis, such as the union.

I believe that with that I will turn it over to Dr. Meister or open it for questions, whichever you prefer.

MR. EVANS:

I would suggest, since these things all tie together, that we just go on through the talks and then hold your questions and then we will send them to the various people as you, the audience, see fit.

DR. MEISTER:

The basic concept underlying Astronautics' efforts to motivate Mercury production personnel can be summarized in just one word, "identification."

Identification here means building a positive emotional link between the production worker and his product, so he fabricates this product with greater than ordinary care.

The difficulty in motivating workers in our highly-specialized technology is that often they don't have any personal tie between their small part of the job and the final product which represents the efforts of perhaps thousands of people besides themselves.

Under these circumstances they might find it difficult to develop feelings for their work stronger than the bare minimum necessary to do the job adequately.

Now our motivational efforts on Mercury centered on personalizing the vehicle and the components going into it. For example, as soon as a component could be identified as being destined for a Mercury vehicle, the special decal that Mr. Dempsey mentioned earlier, representing the Mercury Program, was slapped on it. Now this decal, which you may see on some of the posters around the room, accompanied the component until the latter was assembled into the vehicle.

And then at this stage it was applied to the booster itself and to all of the Mercury spares that accompanied the vehicle. It stayed with the vehicle until just before countdown when, naturally, it was removed to eliminate the possibility of contamination.

Now this distinctive Mercury symbol was also placed on special Mercury posters, as I mentioned, on letterheads for forms used to transmit Mercury components. We used it in newspaper reports and in our own pamphlets.

Now the Mercury decal in itself was unimportant. The important thing was what it signified in terms of the Atlas end product and even more important, in terms of the worker's identification with the astronaut payload.

Now, obviously, greater identification is developed between people and people than between people and instruments and objects, like hardware.

The devices used to push Mercury motivation emphasized, therefore, the identification with the Mercury astronaut.

For example, short inspirational pamphlets handed out to each worker pointed out the relationship between quality workmanship and the astronaut's safety.

A special poster was developed, which I think you will see later on, showing the astronauts admonishing our people to "Do good work."

One of the astronauts played a role in the reliability film "Locked On," a portion of which introduced this session.

We had newspaper articles which hit essentially the same thing. All of these motivating efforts may appear to be rather commonplace and certainly devices such as these have been used many times before. Our purpose in reviewing them with you is to remind you that all production workers have a special need for motivational encouragement and that this need can and should be satisfied in production projects other than the Mercury.

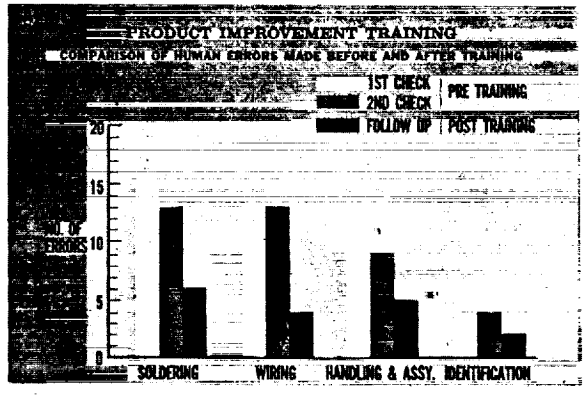
Now, unlike design engineers, who can directly apply their creativity, production personnel need constant reassurance that their work is valuable; that it contributes to some worthwhile goal.

Now by following these principles a state of reasonably high motivation can be induced and maintained. This is shown by our reliability motivational training seminars for workers which Mr. Croft is going to discuss in more detail later on.

Now even in these seminars which are now contractually required on our space launch vehicle project, workers are encouraged to discuss in complete freedom the problems responsible for unsatisfactory workmanship and to recommend their own solutions, to make their own solutions to these problems.

May we have the slide, please?

Comparison of errors made by workers before and after this training reveals a significant error reduction in almost all cases, plus, of course, a more positive attitude on the part of people trained in this way. (Slide 1.)



Slide 1

You can see the difference between the left-hand and the right-hand bar. In each case, it shows a significant reduction in error.

Naturally, Mercury identification wouldn't be complete unless it was passed on to our supplier personnel. Consequently, several reliability seminars were held for a large number of major subcontractors and the motivational program, as well as the special Mercury reliability requirements, were presented in the hope that the same or a similar program would be implemented in supplier plants, and Mr. Johnson of AiResearch is going to discuss Mercury subcontractor programs in greater detail.

MR. CROFT:

Dr. Meister has very effectively covered, I think, the why of training; I'd like to talk just a little bit about how we did the job.

I think our basic philosophy was that we would follow the concepts set forth by reliability, the concept of personal identification and teamwork.

This we did in three ways, first, by presenting an overview of the entire project and each individual's part in it; secondly, by production team training; and third, by training to solve particular problems.

Now, in the first area we presented a rather comprehensive course of familiarization on the entire Atlas booster, not just the particular system or subsystem that an employee was working on. We didn't segregate students by either academic standing or by job classification. Rather, we integrated engineers, technicians, mechanics, inspectors, all into one class because these people were going to be working together on one program as a team.

In the roughly two-year period that we presented this course, we covered some 1,700 students.

In the product team training we approached this with the concept of increasing reliability, improving morale and motivation, building positive attitudes, providing a means of identifying the employee with the product, and a chance for the employee to communicate with his supervisor and to do something about his working environment.

Now our procedure was really simple. A man from our organization would contact production supervision on the first and second shift; we would arrange with that man to conduct a 10-day error check in his particular subgroup. During this time, very quietly, we accumulated the errors that happened in 10 days.

We called the workers together for a one-hour meeting. We used the film "Locked On," and gave them a short motivation on reliability.

We called them again the second day for an additional hour and presented them now with a chart of the errors that had occurred, grouped by category.

We asked these people in the group now to tell us what caused the errors and we asked them also to provide remedies, tell us what could prevent the errors; what were the barriers that they faced.

Then we did some follow-up, some corrective action, and at some time within the next 30 days we came back, unannounced, and made a second 10-day error check. We again called the group together for a final session to pat them on the back and to show the comparison between the first error check and the second error check, and in every case the error reduction was very significant.

In fact, in 10 groups having to do with Mercury production, the average reduction in human error was 40 percent; in one group, it was as high as 70 percent.

The smallest reduction that we noticed in any place was 20 percent.

This program really has a lasting effect also, because we indoctrinate the supervisor to follow up in this program and to continue it. We come back periodically, six months, eight months later and give them another little short, shot-in-the-arm version.

Now, our third area that we concentrated on was the special problem courses, higher skill certification, classes on particular subsystems, such as the "ASIS" or the abort sensing system.

We also got involved in clean room techniques and reliability training of various kinds, such as failure and consumption reports.

Then we invited subcontractors in for seminars and asked them to take back information to their plants and apply it as they saw fit.

Mr. Johnson is going to talk a little bit about what the subcontractors did.

MR. JOHNSON:

Thanks, Jack.

Well, as a representative of but one of the large group of suppliers in the Mercury-Atlas team, let me tell you the program established by the Garrett Corporation to "do good work."

After the December '59 Astronautics subcontractor workshop, our people returned resolved that much effort must be put forth to get the message across, to start the requisite training to review the adequacy of facilities. From this point on, I will speak specifically of AiResearch, Phoenix, program, though a parallel program was carried on at a Los Angeles facility.

A 10-minute slide presentation with tape sound was put together. Seven basic slides were provided by Astronautics. These were augmented with others showing the many AiResearch products involved; their function, location, and use.

The slide projector and amplifier were mounted on a small cart and moved in and out of all areas of the plant. All shifts were covered in bringing the message to groups of 20 or 30 employees at their work stations on company time. Some 140 presentations were made covering the 3,500 employees at Phoenix.

This was followed by a 10-week poster program, utilizing 10 different multi-color silk screen posters. These were designed chiefly for the AiResearch, Phoenix, Mercury-Atlas Program. Fifty different locations were posted.

Concurrently with the poster showing plans for a training program of inspection, QC and other guarantees were established. A panel was drawn up to provide classroom training sessions for some 300 persons involved in the manufacture of Mercury-Atlas and other control systems components.

Immediately following the poster campaign, each individual received 40 hours of training in production methods, as well as basic engineering concepts and requirements of the Mercury-Atlas Program.

Training sessions were held during working hours; sessions were limited to an hour and a half and presented twice weekly to groups of approximately 25 employees. Engineering employees, selected for ability to instruct, presented the course material.

Special care was taken not to talk down or to overly simplify the material presented. Reception of the training was very good.

The results of the individual, final examinations were very encouraging. The program is still being carried on on an as-needed basis to indoctrinate new personnel.

And while these training programs were in progress a good look was taken at facilities available to do the job. We were determined that this would not be an instance where management talked up the need but didn't follow through in providing the wherewithal.

As a result, starting as the training sessions were nearing a close, assembly areas were completely cleaned and repainted from top to bottom; improved planning for work growing and progressing resulted in a completely revised layout of the area; floors were tiled, work benches and work areas were redesigned for a minimum of clutter and a maximum of utility. Our white rooms were completely refurbished and brought up to the state of the art as it then existed.

This in-plant program covered some, I would say, nine months from January through September of 1960.

While this was going on, in February of 1960, we held our own supplier seminars with some 60 major suppliers to us, primarily castings and forgings and the more critical components of the items we produced.

Three seminars were held; we refurbished, brought up to date an existing supplier control manual; updated a supplier rating program, but in general I would say that our effort was a complete magnification and greatly implemented supplier control programs, roughly three times that which had existed before.

The program was not inexpensive. Out-of-pocket expense approached a hundred thousand dollars. However, results were more than gratifying in terms of employee attitude, cooperation, and performance.

Within a 12-month period errors detected dropped to one-third of the previous level. It is interesting to note here the comparability of results with those of the Astronautics program, as reported by Jack just a few minutes ago.

We conservatively estimate that the dollars spent in this program were returned in less than one year, but of greater significance, however, is the successful mission history of the many vital AiResearch components which are part of the Mercury capsule, the Atlas booster, and associated ground support equipment. The design and manufacture of successful space equipment is a tremendous challenge and as is General Dynamics, and NASA, and the Air Force, so was AiResearch dedicated to meeting this challenge and advancing the state of the art and in crossing the space frontier.

I have mentioned slide and poster programs we have used. I am sure that Vern Heger has a great deal more to say on this subject of visual devices.

MR. HEGER:

As Colonel Hoffman mentioned this morning in part of his speech, things went well in the Mercury Program and I feel particularly this way about the visuals we used. Sometimes you think of these materials as art for art's sake.

Fortunately, in the Mercury Program there was a design, a problem posted; there was attempt formed and therefore the visuals could be specifically pointed for definite purposes and to definite audiences.

Now, rather than talk any more about it, I thought I might show you some of the actual visuals we used.

If we could get the lights down a little bit, please.

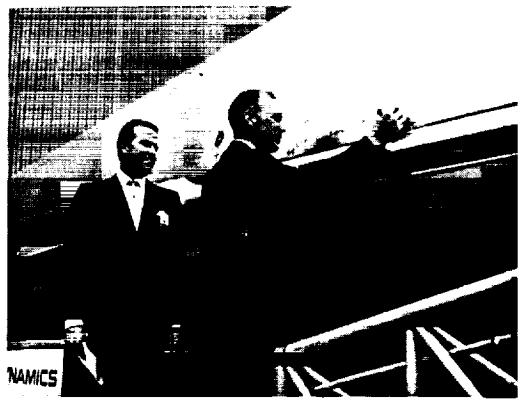
Although I am talking about visuals and I use the astronauts as visuals, in quote, but they were a strong factor in our motivating program. They visited our plants. (Slide 1.)

Slide 1

There is Cooper and he wrote on one of the Atlases, he said, "Launch this way." (Slide 2.)

The launch conductor followed and said, "O.K."

These kinds of things occurred. People were made aware of them and it did a great deal to heighten and point up personal interest in the program.



Slide 2

Glenn, after his flight, came back, went over to the Electronics Area and the gals there that put these very intricate things together just simply mobbed him. (Slide 3.)

Our company publication, "General Dynamics News," was used extensively in disseminating to all our employees all kinds of information about the Mercury Program. (Slide 4.)

Slide 3

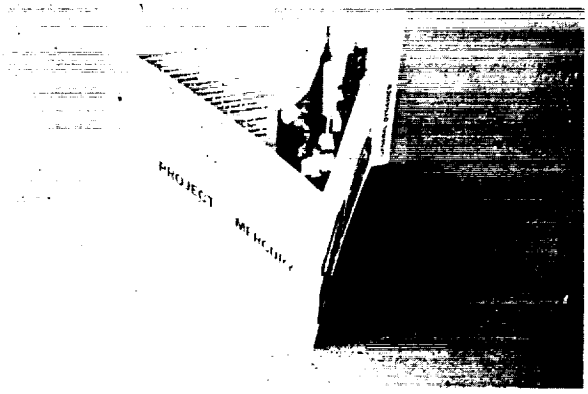
We made up special brochures that were given personally to every worker concerned in the program. That brochure, by the way, was sort of a run-down history thing. It wrapped it all up so you could have an idea of what the whole program was about. (Slide 5.)

This is that poster that's been mentioned before. That is the astronauts as they were leaving. (Slide 6.)

Slide 4

He said, "Do good work." These were put up in over a hundred locations around the plant and were provided, if desired, to subcontractors.

Here is a poster which was placed throughout the plant. That shows the Air Force Commanders, Joe Moore. (Slide 7.)



Slide 5

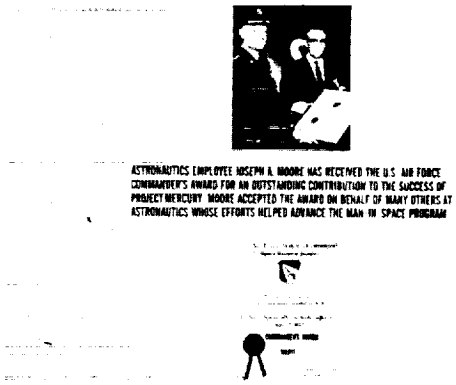
These Mercury pins were sold by our employee services group. They were available for purchase by all employees. (Slide 8.)

The same way with the little photo pack. After a successful flight or some part of the program, these series of photos were bound up with a plastic binder and put on sale at employee services. (Slide 9.)

Slide 6

There is the Mercury capsule which McDonnell used and which we found all over our plant also. A very powerful device to identify people with projects. (Slide 10.)

The employee badges that identified a worker as a member of the special checkout team. (Slide 11.)


ASTRONAUTICS EMPLOYEE JOSEPH A. MOORE HAS RECEIVED THE U.S. AIR FORCE COMMANDER'S AWARD FOR AN OUTSTANDING CONTRIBUTION TO THE SUCCESS OF PROJECT MERCURY. MOORE ACCEPTED THE AWARD ON BEHALF OF MANY OTHERS AT ASTRONAUTICS WHOSE EFFORTS HELPED ADVANCE THE MAN IN SPACE PROGRAM

Slide 7

In addition to identifying people with symbols, work areas were called out on the final assembly line. (Slide 12.)

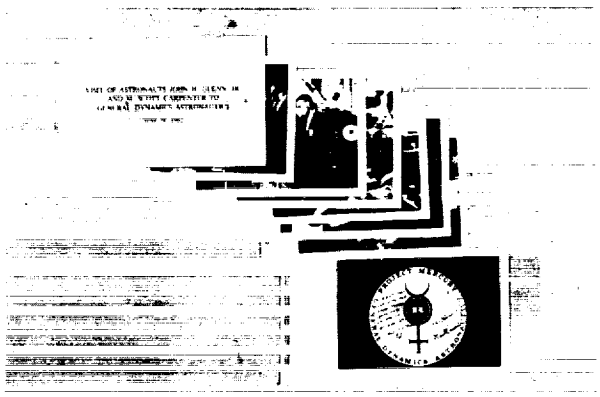
This is the sticker, the decal which was put in custody of inspection and the small ones were put on critical components so that as they moved through the shop employees were aware of the importance and the critical nature of this part. (Slide 13.)

NASA
PROJECT
MERCURY
Combining the ancient symbols for the planet Mercury and the universe, this pin depicts NASA's historic Project Mercury, in which U. S. astronauts achieved the free world's first manned orbital flights, boosted into space by Atlas Space Launch Vehicles, manufactured by General Dynamics Astronautics.

Slide 8

Here is one attached to a canister. (Slide 14.)

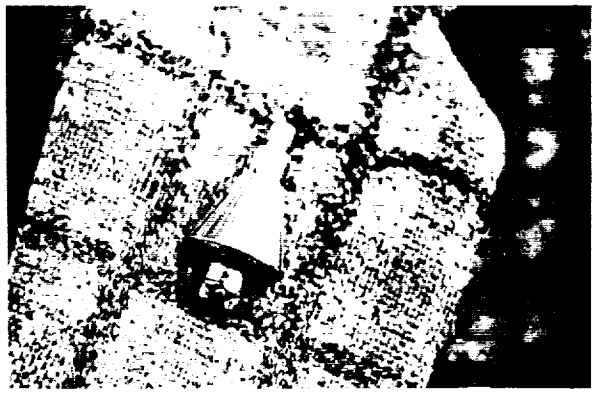
You see some of the large ones there on one of the birds and the Mercury line. (Slide 15.)



Slide 9

Now I might point out in this production line, of course, you have other weapons systems missiles going through, so the problem is to -- our problem was to call out the special nature of this particular project.

This is the last of the slides and I wanted to say a few things about it. (Slide 16.)



Slide 10

First, the reliability symbol in the center of the Mercury symbol was something that had been started as a program in Astronautics way back in 1957, I believe it was, and had well-known characteristics already in our organization.

The incorporation of this in the Mercury symbol and the legend around it made this one of our strongest visual devices.

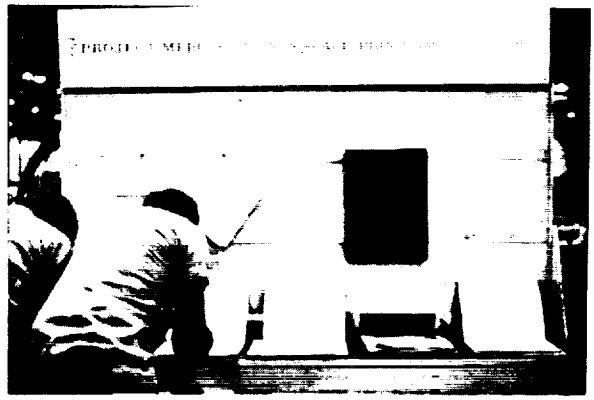
Slide 11

I guess the point I really want to say about visuals is that by themselves they are not anything, but they do reinforce and point up programs

that have received management concern; that have been communicated in training sessions and by special organizational features in organization.

Visuals, by themselves, without adequate background of personal knowledge of what they mean are not very effective, but when you have a continuing program going, and you can put a few things in front of the people that point up and reinforce this, then you really make visuals pay.

Thank you.

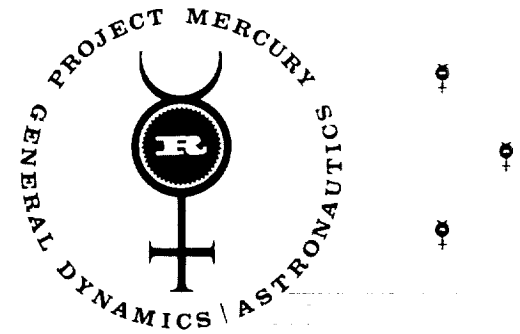


Slide 12

COLONEL BRUNDIN:

Next, we would like to hear from Pete Richardson, followed by Mr. Rovenger, who represent the people on the spot from NASA and the Air Force in the General Dynamics plant and to tell you how they participated, supervised, and assisted.

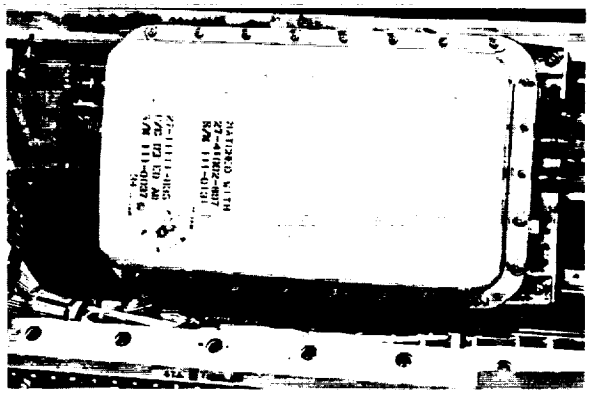
Pete.



Slide 13

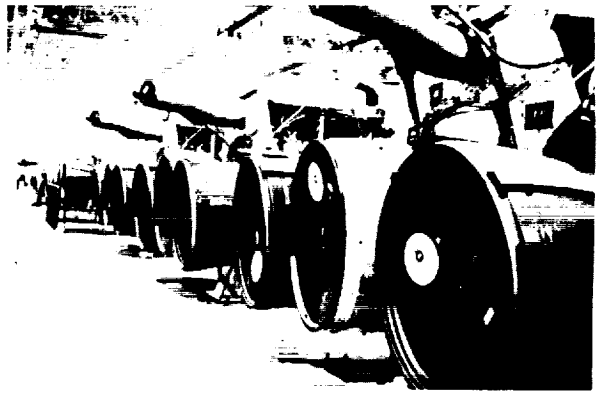
COLONEL RICHARDSON:

I think that motivation at the worker level certainly has to be buttressed by motivation



Slide 14

at the management levels, and the through procedures as will fall in this category.



Slide 15

An example here, the failure analysis program wasn't resulting in corrective action any faster than on an average of about four months. The people certainly can't be expected to maintain a level of motivation if the things they see around them aren't doing the same type of thing.

Slide 16

On the people's side, I think that what we did here was meld the Air Force, the procuring agency, with the contractor and interfacing problems and this was done with a working group concept in the plant.

This is a sharing of responsibility between the procuring agency and the contractor, but I think that it solves the problems faster.

Mr. Rovenger is the NASA representative upstairs in the Astro plant.

MR. ROVENGER:

Thanks, Pete.

I am sure that the thing that makes the Mercury Program successful is the thing which makes all good programs go, and that is attitude. By that, I mean positive attitude on the part of the people engaged in a program.

Without it, nothing goes right and no program is really going to be a success or succeed as well as it might.

I think to use Mr. Dempsey's little triangle that he explained this morning about cost, reliability, and schedules, if you don't have the right attitude on the part of people, and this is from management on down, your program doesn't go as fast as it might or as successfully as it might, and therefore the cost is going to go up. Your reliability is going to go down and your schedules are also going to move to the right, never to the left.

I think that the positive attitude on the part of people in the program, that is all your supervision, many people down below, is the most critical factor in getting any program to success. This it true, I am sure this is the thing that made Mercury go This is true in other successful programs when you go to the heart of it.

If you don't have the willingness to change methods, procedures, organizations, to change personnel when people can come up with a hundred reasons why not to do a thing, rather than one good reason how to get the job done, if you can't get that kind of thing, you don't have a program that is going to be a success.

I am sure this is the most important thing that has made Mercury the successful program that it is.

MR. EVANS:

I would like to open the meeting to discussion now.

I only ask that if you wish to present a question, would you please just announce you name and affiliation, and if you want, direct your question to a specific man; if you want a general question, address it to me, and I will assign it.

The only reason I am taking over here from Colonel Brundin is he is probably one of the most experienced people we have and if he is chairman he can't respond.

Let's get him during this discussion.

MAJOR WOOSTER:

Major Wooster from SSD.

I have found the discussion quite enlightening. I would like to ask one question which has bothered me a lot, and hopefully, some other people.

How do you extend the Mercury human factors beyond a program?

In other words, from GD/A?

MR. EVANS:

I knew you were going to ask that question. I would like to let Mr. Rovenger take a crack at that.

We are working on the Centaur program at the present time; maybe he would like to comment on that one.

He didn't say much before.

MR. ROVENGER:

I though I said a whole lot.

MR. EVANS:

In time, I was talking about.

MR. ROVENGER:

How do you extend one successful program, the way one successful program works to another. Is that essentially what you are asking?

MAJOR WOOSTER:

That is basically it.

In other words, from GD/A's viewpoint, if all Atlases had the same success as the Mercury Atlases, think where GD/A would be. So it is their problem, really.

If they can solve their problem, I will know how to approach mine.

MR. EVANS:

Maybe Mr. Rovenger will tell you certain pressures he is putting on us to solve that problem.

MR. ROVENGER:

We are living with that problem right now, to get the reliability in the Centaur Program that we have in the Mercury Program.

How do you achieve it?

Well, I think I really said it before, it is by getting the kind of people in a program that have the right and positive attitude and the will to do the job as quickly and effectively as they can and you try to get people with experience and with this attitude and bring into any new program those things which have proved to be successful in other programs, but you also have to relate those to the people involved.

What was successful in one program may have been successful because of the guys involved in it and you can't always bring it directly over to another program. You may have to invent another tack, depending on the personalities involved; use that for a starting point.

Again, it comes down to, also in a program, the people with the will to get the job done, regardless of red tape, obstacles thrown up in front of people; they have got to figure out a way to get the job done.

MR. EVANS:

Colonel Brundin is itching here. Let's hear from him.

COLONEL BRUNDIN:

Charlie and I have talked this over many times in the past.

I think if you are referring to such things as component selection, reserving them for Mercury, you are entirely right. Mercury was unique

in this respect and we enjoyed a very high status, but when you are talking about personal motivation, Charlie, I think that it is perfectly conceivable that there is a benefit to be gained between competition between such programs as Centaur and Mercury or Ranger and Mercury.

There is a limit to how far you can push it and certainly it has to be a sincere and an honest motivation. You can't fool anybody trying to generate interest in something that you yourself are not sold on.

But I think that you and Major Jack Helpert did a pretty good job on Ranger and I think it can be done within the same company.

MR. EVANS:

Colonel Richardson wants to talk.

COLONEL RICHARDSON:

I wanted to point out that many of the things that were done for Mercury are already being implemented into the SLV Program (space launch vehicle program).

I think in the failure analysis program, Mercury really had to use every bit of failure information possible that came from not only the Mercury boosters and its systems, but other boosters and, in fact, the missile itself, as a weapon.

MR. EVANS:

I would like to ask Jack Croft to talk to us specifically in connection with the soldering certification.

MR. CROFT:

Skilled training and product improvement as talked about applied equally well to all programs. It doesn't work just on one.

In our plant, groups that we worked with were not working just on Mercury in many cases, but were working on many programs so we approached this with, "How do you increase reliability and motivation over all, not specifically just Mercury."

MR. EVANS:

Do you want to continue, Dick, before we leave this?

MR. KEEHN:

Yes.

Charlie, there is one thing that is going on and being developed out at the plant in regard to your question and it deals with the establishment of competitive rating for each department within the plant.

Now this is a complicated thing to establish because of the varied tasks within the various departments.

It is difficult to put design engineering and production on a comparative basis, yet we feel that it is not impossible and it is our goal to establish a realistic competitive rating figure for every department which will deal with the number of rejections in the case of production departments; in the case of the support departments, it will be based on the number of times you've got to do a drawing over. For instance, in order to get it right, or in the case of planning departments, how many times did they have to do a piece of planning over before it was satisfactory.

But in all cases there is some basis for evaluating the performance of a department and we want to put it on a competitive level and then advertise this competition and play it up to get real competitive spirit going among all the employees.

MAJOR WOOSTER:

Well, you are saying that you are actually applying the suggestion Colonel Brundin makes in the process?

MR. FERISH:

Preston Ferish, Marshal Space Flight Center, Huntsville.

I might say, this meeting has been very enlightening to me. It is more than what I expected when I came here, because I was looking at

more what may be some failure effect analysis and reliability and that point, but I would like to say this, that we are trying and intend to initiate a type of program that you are talking about right here at Marshall into the Saturn Program, and certainly we would like to be able to call upon you gentlemen to aid us in this, and one think I would like to ask you though, what do you call your program? What do you call it, reliability awareness program, what heading do you use? What is the nomenclature?

COLONEL BRUNDIN:

Pilot safety and quality assurance program.

MR. EVANS:

That was in the Mercury.

MR. FERISH:

Yes.

Well, we intend to call ours "Man Flight Awareness Program."

MR. EVANS:

All I can say is, be our guest. We will be glad to help you.

MR. FERISH:

I am very pleased that I came, really.

I was directed to come and --

COLONEL BRUNDIN:

I would say that is a supreme compliment.

MR. EVANS:

I will only comment on that there are different kinds of motivation.

MR. GOITER:

Walter Goiter, General Dynamics Corporation.

I realize the Mercury Program has only been completed very recently, but presumably these highly motivated Mercury teams have been directed to other programs or dispersed. I wonder if you have any occasion to check the performance of these individuals in these programs, in other programs?

In other words, is there any habit-forming aspect to this?

MR. EVANS:

Do you want to comment?

MR. KEEHN:

I am not sure of what I am going to tell you, based on any survey that I have run myself, but I know personally, oh, I would say 75 to 90 percent of the individuals that were involved on the Mercury Program here in the factory, and I know upon a personal basis perhaps 40 percent of all the rest, and there isn't any question in my mind but that these individuals are going to be leader types in any group that they go into and that this experience that they have gotten on Mercury and that the one feeling you get inside when you have done a good job is going to spread over to the other groups as well.

MR. EVANS:

I only say here that there is a good example, Dick Keehn.

I heard a cliche once, "quality begets quality."

Maybe Dr. Meister would like to comment on this aspect from the other employees' point of view.

DR. MEISTER:

I think I would like to address what I have to say to the Major's original question, what can be carried over.

I think there are some basic principles that have been discussed here that apply to any kind of a development production project, regardless of whether it is Mercury or something else.

I think some of the important things, especially with regard to production personnel, some of the important things are the personalizing of the work that they do, the attempt to have production personnel understanding what they are doing in relationship to a larger goal; the necessity for utilizing the experience that these people have in efforts to remedy any problems which are outstanding, and in this respect I might say, my own personal feeling is that these motivational training seminars that we have had are perhaps the most successful aspect of this motivational effort of ours, because and primarily because they have allowed the worker to feel that he is more closely tied to the total program.

MR. EVANS:

Maybe Mr. Johnson would like to comment.

MR. JOHNSON:

I can only agree at this point.

MR. EVANS:

That was your line, anyhow.

MAJOR WOOSTER:

Could I made one comment here?

This personalization -- I had another question, but it doesn't deserve discussion here, it is too involved. I am sorry.

I would like to find out where you can get the techniques that you use to control this personalization thing.

How does a man warrant a Mercury badge and this sort of thing? Who should I talk to at some other time?

MR. KEEHN:

Come and see me any time, Charlie.

MAJOR WOOSTER:

O. K.

MR. EVANS:

One other thing I want to mention, I think pointed out by Colonel Richardson, that the same techniques have now spread to SLV and to the Centaur Project, both the improvement program, the required soldering and welding certification type recognition, and I think also I might comment that we have been able to talk more about building fences around employees and, Jack, do you want to comment on that one?

It is a stabilization of employees within their activity, or maybe I should -- Do you?

MR. CROFT:

I think you have covered it.

MR. EVANS:

I think the union relationship has certainly tightened in this area, especially we have had a real close rapport on this soldering certification and welding certification program where we brought the groups together and we have been able to augment this stabilization concept.

MR. LOVELL:

Jack Lovell, Martin Company, on the Gemini Program.

I guess my first question would be to Mr. Heger.

Some time ago, about a year or so ago, we obtained a copy of your "Locked On" film for review of our employees and I don't recall who we coordinated it with here at GD/A, but I would like to have the name of the individual.

I would like to get this thing back in motion again if we could.

MR. EVANS:

Vern Heger.

MR. HEGER:

Do you want the name now?

MR. LOVELL:

Would it be you?

MR. HEGER:

It could be, since my name is --

MR. LOVELL:

I will contact you later.

The other question I guess was on Colonel Richardson's failure analysis.

Correct me if I am wrong, Colonel, I understood on internal failure analysis you indicated something about four months lapsed time between supplier and yourself.

COLONEL RICHARDSON:

This is the situation that we realized we had.

MR. LOVELL:

Could I have a few details as to how your internal working group brought this to a head so you wouldn't have this time?

COLONEL RICHARDSON:

It wasn't the working group. I think it was a study of the problem and a solution which really was to put suspension dates on the close-out of failures, corrective action, and no booster left the factory with any failures unanalyzed and without corrective action having been taken that might affect that booster.

No booster was launched with open failure analysis, which might affect its performance.

MR. LOVELL:

Did this internal working group end up making visitations to suppliers' facilities or was it strictly an in-house thing?

COLONEL RICHARDSON:

Yes, the working group faced a whole mixture of problems and one of them, of course, was questionable subcontractor products and in these specific cases we did visit and discuss the problem with the subcontractor.

MR. LOVELL:

Is this group one of the groups that was referred to as your Tiger Team or something like this?

COLONEL RICHARDSON:

No, this is a separate operation from the Tiger Team but I am sure the Tiger Team did the same thing.

MR. LOVELL:

A separate entity, but it was tightened?

COLONEL RICHARDSON:

Yes.

MR. JAMES:

Preston James, Burroughs Corporation.

Most certainly this very big effort must have had some effect on schedules. What was the effect generalized on the end result, let's say?

Did it extend finally?

MR. EVANS:

You are itching again, Colonel?

COLONEL BRUNDIN:

Well, we had to accept the fact that we might have delays in order to live up to this program.

Such things as delivering boosters with no shortages, this sort of thing, initially people told us we were crazy; there had never been an aircraft delivered to the Air Force without a shortage of some kind, but this was achieved on 109, wasn't it, Dick?

MR. KEEHN:

Yes, 113.

COLONEL BRUNDIN:

We came very close to it, in a matter of one, two, three shortages, some of which the Air Force caused, on all of the others.

We did insist a couple of times on reruns of composite tests and this took a minimum of two weeks.

Right, Dick, every time we made this decision we had to accept delays, but as was pointed out by Walt Williams, we did not let a bird go from this factory with anything in doubt about the bird and we did not let a bird get launched with something in doubt, and you have to expect schedule delays on this basis.

Dick?

MR. EVANS:

This man.

MR. NADABAL:

Ted Nadabal of North American.

You almost took the heart out of me with that, because I had formulated my question and then this one came up and it even takes more courage now that I hear your answer.

But I strongly suspect that the supervisory level, while they may be well motivated, are motivated somewhat in a lopsided direction, that is in favor of schedule at the expense of quality.

I think this is tragic, because in my own opinion, an improvement in quality actually enhances schedule.

Now my question is, do you agree with this and if you do agree with it, has the panel any ideas on how to, let's say, correct this lopsidedness?

MR. EVANS:

Well, if we say we don't agree with it, then we haven't got a problem.

MR. NADABAL:

Well, take the easy way out if you want.

Another way of putting it, I say, it is cheaper and you can do the end job faster if you do more of the items right the first time.

COLONEL BRUNDIN:

No question.

MR. EVANS:

If I am against that, it is like being against motherhood.

Dick, do you want --

MR. KEEHN:

Yes, I would be glad to.

There is saying that has been passed around most companies and it is rather prevalent around ours. I won't say it is any more prevalent around ours than others.

It is strange that we never had time enough to do the job right but we always have enough time to do it over, and this is something that we have fought continuously on the Mercury Program and your initial, or one of your initial statements, about the first level of supervision, the employee on the floor being more schedule conscious or quality or cost conscious probably prevails on most of the programs, with the exception of the Mercury Program, and here we drag this man into all of our sessions, everything that involves this program involves him too.

In many cases, he has even made trips to the Cape after his missile had been delivered to let those people on the receiving end take a whack at him if they wanted to, because he is the guy that built it. He is the guy that sent it to them supposedly ready to fly and if there is anything wrong he has his neck on the rack.

MR. EVANS:

Frank, do you want to comment on this?

MR. TRAVERSI:

Frank Traversi.

I am not one of the experts on the panel; maybe I shouldn't comment, but I think the key in answering this question is something that Jim Dempsey touched on this morning, and that is that there is a fine balance between the three factors.

You can't perform a task of this nature or any other nature by placing greater emphasis on one and de-emphasizing either or both of the other two. So, when Dempsey talked about conflicts, there is a conflict between the three factors but I prefer to refer to it as a fine balance between the three, so that you don't go all out for schedules, for instance, and disregard liability, or cost, or you don't go out for reliability and schedules at price no object.

So it is a balance and I think what we are trying to do and what we have done in the past was to motivate supervision and the workers to recognize the balance between the three.

I don't know whether or not that answers your question, but we are now trying to exclude the thing of first-line supervision by training them and by motivating them.

We are trying to get them to bear in mind the balance between the three factors.

MR. NADABAL:

O. K., but if you are convinced that they have the wrong balance, then how do you, if -- and this is a very important if -- if you are only on their same level or perhaps lower motivate them in the direction of the proper balance?

If you are the president it may be easy, but if you are not, it is a different story.

MR. EVANS:

Well, Mr. Traversi is vice-president of balance.

Next gentleman, he is the vice-president of administration.

MR. SIMKINSON:

Simkinson of NASA.

I was wanting to say something but I think this gentleman's question is real pertinent. I have some data, if I may, that I think should be looked at.

I believe that we had a situation during the first part of this program, that was before we had a team working. We haven't spoken about this area today yet, I don't think. One man touched on it lightly, but we didn't get there in one day. I am sure all of us will admit this.

And I have a sheet here which shows the first four Mercury Atlases prior to the time Walt Williams mentioned, where the Russians did in fact beat us, and prior to our really taking a good look at this problem, many of us were schedule minded, a little bit too much. Everybody thought that was the way to get there.

This says that we ran two composites and we had unsuccessful flights.

Over a year later, because of many problems, we didn't fly it right, we came to the second one; again, as you will see, it only had one composite, '60, '63. One was a successful flight. Significantly, it had three composites.

We thought we knew how to do it, so we went back to one composite; we had another failure.

The next one, I believe we ran 11 composites and we haven't had a bad one.

Eleven is not significant at all, but we did run three, four, five, six on all the rest of them and we went straight through the program and I think your answer is right there in what quality does -- meticulous attention to detail does buy you schedules in the long run.

MR. EVANS:

Let me say here, now, that all the administrators of this program are yelling time and so on. If you want to go ahead and stand in line for lunch, go ahead.

Anybody that wants to stay, we will be happy to stay for a few more minutes. We will be happy to continue the discussion. I guess what I am saying is that anybody that wants to leave, leave.

Colonel Brundin wants to comment on this, I believe.

COLONEL BRUNDIN:

Scottie, this brings up a point and I don't think we made this clear. We didn't begin this program like that. It grew and Scottie was a tremendous help to us out here in San Diego and I am real sorry he isn't on the panel today, because I am sure he has many more good points to make.

MR. EVANS:

He is on it. He just got up and spoke.

COLONEL BRUNDIN:

This program grew from a concept and was implemented by the contractor and things added and I am sure many things came from Scottie himself. It wasn't something that was put into effect overnight and I think in all fairness you are talking about a time period when we were kicking this off, right?

MR. SIMKINSON:

Yes. We had to learn. That is what I am saying.

COLONEL BRUNDIN:

These were the boosters in the time period when we were really learning and the purpose of this whole workshop is to pass this on to you so you have a better place to start in these other programs.

MR. SIMKINSON:

I didn't want anyone to get away with the feeling, Colonel, that we thought quality would still cause us delay. We got through this program in good shape because of quality.

MR. EVANS:

O. K.

MR. RICHARDSON:

Bill Richardson, Hughes Aircraft Company.

In discussing reliability here you have discussed two separate general factors, one, motivating people; the other you have discussed -- or was discussed earlier was the ability, because of your large production runs, to accomplish part selection.

I wonder if you could sort of weigh the relative merits of these two, because of many space programs, as you know, the payload programs and such, you don't have large production lines.

MR. EVANS:

Ron.

MR. ROVENGER:

I think you bring up a problem which is pertinent in our own program, which we are going through right now with Centaur. We don't have large runs and initially we took what was left over from the Mercury Program in the plant. This was what everybody else, so to speek -- this is not a derogatory remark, but it is a factual one -- Mercury Program, because of its man-rated problems, got first priority in everything which came into the plant and things were given special attention and the other programs took second choice, which was acceptable but not up to the high standards of the Mercury Program and this is one of the things we learned in the Centaur Program.

For instance, we have had repeated failures on component levels. It is a problem of education of all suppliers and vendors in the program, that program which we are all involved in, do not have large runs and every firing must be successful.

We all have to have a hundred per cent reliability, which is the goal, not the theoretical one any more, one which we must all achieve.

Shots cost so much to come to that we can't afford any kind of failures and the way we believe to do it now is implement a program where all the

components are built to much higher standards than were ever set forth in the ballistic missile programs.

All programs will be receiving components equal to what Mercury got or better. This is the way to go to achieve the reliability which we all need.

MR. YOUNG:

M.A. Young, IBM Corporation.

I would like to direct this to Dr. Meister on this matter of identification and it really relates to the last question.

What problems do you see in this business of identification as a means of motivation that would arise from multiple critical in-plant programs?

I can envision situations of symbols floating all over the place and you lose the whole impact. Would you care to comment on that?

MR. EVANS:

Do you want to go to lunch before you comment on that?

DR. MEISTER:

I don't think that it is necessary to build up a special, a competition among different kinds of projects in order to be able to personalize the product and the project to your individual worker.

Sure, if you have ten different projects and you don't want -- you wouldn't necessarily want ten different symbols floating around, but the symbol is just the surface of this whole thing. The idea behind the symbol, behind personalization, is to let the worker know what he is doing in relationship to the ultimate goal of the project and to make him feel a part of this team that so many people have been talking about.

Well, I think when they use the term "team" around here they are possibly thinking about engineers and test personnel, but I think that it is perfectly possible to make the worker aware of his role in what he is doing without engendering any unnecessary competition.

Obviously, we are every day, all of us, responding to many things and they don't necessarily set up a competition. It so happens that in the particular Mercury situation it was a case of comparing, not really comparing, but you had two separate projects going on simultaneously, one of which had a somewhat higher priority, but I think it is perfectly possible to apply the same principles even though every project, every product has an identical priority.

The competition, in other words, is not the necessary element.

THE FLOOR:

Let me ask, did you see any depressing effects on the non-priority projects?

DR. MEISTER:

Perhaps Mr. Keehn, who is in charge of these teams, could answer that question a little bit better than I can.

All of the workers were exposed to the Mercury propaganda and at certain stages in the production line all of them would have been working on components that might eventually wind up on a Mercury bird, so I personally can't answer that particular question.

Perhaps you can, Dick.

MR. KEEHN:

I don't think that there was any measurable depression in the other teams. I think this was borne out primarily by the fact that the other teams were constantly watching the Mercury teams because they wanted to get on that team if they could and it was pointed out to them that replacements on that team would be necessary as people moved around and changed jobs occasionally and the people to replace any of these people would be chosen on a highly selective basis.

So each of these other people tried, I think, just a little harder to put themselves in a position to be chosen for that.

MR. EVANS:

The next gentleman?

THE FLOOR:

I would like to address a question to the panel in general.

How do you think you can keep the integrated motivation on a rather large program such as Apollo, which is long-haul and involves many primes and associate contractors?

COLONEL BRUNDIN:

Well, we kept it going for, I guess, you might say three years and I, at least when I left the program, and perhaps Scottie can add something to this, or Pete, I never saw any letdown in this team.

As a matter of fact, it grew, and although there is a great deal of personal sacrifice in keeping something like this going, I don't think it is inconceivable that it could be kept going for the length of the Apollo Program.

Do you, Scottie?

MR. SIMKINSON:

I am sure Pete could answer it better because you and I left about the same time.

I surely would agree with you what I have seen coming back now, right, there has been no letdown that I could see.

There may be one now if we aren't careful.

COLONEL RICHARDSON:

Well, I think there are indications that there might be a little bit of decay here, a little slump, but I don't see why there can't be a recovery. I think the total number of failure analyses issued on a rate basis has somewhat dipped since the end of the Mercury Program.

Am I covering the question?

THE FLOOR:

Yes, I was also interested though in how you keep the total picture in front of you, so many different organizations.

For example, in a large program, in the Mercury Program, you had one booster contractor with subs and in Apollo you have several, and the problem is just generally larger.

COLONEL RICHARDSON:

Well, of course, it is costly. The whole thing is costly and the contracts written must take care of the additional costs. You can't get blood out of a turnip.

MR. EVANS:

I sure wish it was General Dynamics' problem. We'd love to tackle it.

With that, I would like to say that the panel members will be at the sessions during lunch and all afternoon. I would like to adjourn from my point of view and turn the meeting over to Colonel Brundin.

COLONEL BRUNDIN:

Thank you very much for your participation and I hope it has been worth while.

(Applause.)

(Whereupon, at 12:35 p. m., the panel discussion was closed.)

Subject Supplier Coordination

Time 10:45 to 12:00 noon

Location Sunset Room

This panel will examine three aspects of supplier coordination; vendor evaluation and selection, purchase order control, and vendor corrective action. Panel members are:

Col. F. E. Brandeberry, USAF, Chairman
Mr. J. H. Johnson, Astronautics, Coordinator
Mr. S. Braun, Astronautics
Mr. J. W. Cook, Kearfott
Mr. C. Hargiss, Rocketdyne
Mr. L. I. Medlock, Astronautics
Mr. D. E. Moore, USAF

COLONEL BRANDEBERRY:

Gentlemen, for the benefit of you people sitting over here (indicating), there will be a few slides shown. If you are unable to see the screen, maybe it would be better if you fill in the spaces over here a little bit.

Good morning, gentlemen. This is a panel on Supplier Coordination. I would like to welcome all of you to a discussion which I hope will be informative and beneficial to you and your organizations during your endeavors in space work.

During the next hour and fifteen minutes you will hear short talks by my panel members who have had a definite part in the over-all achievement in the success of the Mercury program.

During your period here with us you will hear comments on the importance of reliable suppliers and vendor selection. Then you will hear comments on vendor selection and controls, supplier seminars, customer interest and controls, and the relationship to General Dynamics/ Astronautics programs and individual efforts undertaken.

After each of the last groupings there will be about a six-minute question and answer period that can be carried on, and then upon completion of all of the prepared talks that we have for you, there will be about a ten-minute over-all question period.

When you ask a question, I would appreciate it if you would give your name and organization so that the reporter here can take that information down.

You will get a copy --- if you have filled out the proper blank in the lobby --- of what goes on in all of these panels. I realize it is hard to be in three places at the same time when we have three different panels going on. So this is one way to catch up on what went on before.

I would like to take just a few minutes of your time and talk to you on the importance of having reliable suppliers.

We have made fantastic advances in the aerospace field -- many of these advances have been made in the last three or four years.

Our concepts have been broadened to include space travel, not as a theory but an actual reality. We would not have achieved the goals we have today if emphasis had not been placed on reliability. Reliability today is the keynote of our space programs.

Our space systems must not only possess orbital capability but also, in many instances, be capable of earth re-entry and safe recovery. These vehicles must perform reliably in varying environments.

"Reliable" is defined as being suitable or fit to be relied on; trustworthy.

In our advancing technology and structured economy we do not expect a given individual to develop and produce a new vehicle or system. Many thousands of individuals are involved in our space programs. We rely on our suppliers with unique talents to produce our components and on our integrating contractors to manage the multiple interface problems associated with a system. Each of these contributors must be reliable. The concept of reliability must be permanently impressed upon the minds of those individuals whose products go to make up the sum total of a system. The failure of even a minute detailed part can doom an entire vehicle or system. The importance of reliable suppliers cannot be overemphasized. The high cost of pay loads -- sometimes one of a kind -- and our participation in the technology race that we are in today requires that there be no failures.

This workshop session will provide us with some of the details of supplier coordination.

A representative from the airframe contractor, Mr. John H. Johnson, director of Management Systems, who is responsible for all systems and procedures, business and scientific data processing, and computer operations and configuration management in GD/A, will give us some of the things on the importance of vendor selection.

Mr. Johnson.

MR. JOHNSON:

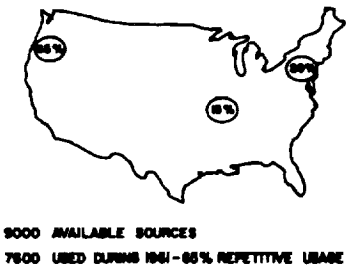
You are probably wondering what the relationship is between computer operations and computer data processing and reliable suppliers. This is a new field for me. I spent probably ten years in the field of supply evaluations. So operations is a new phase.

I have a few slides at the outset which may assist us.

We consider reliable sources to be the lifeblood of any contractor. Without the assistance of reliable suppliers, none of our major space programs could have been completed.

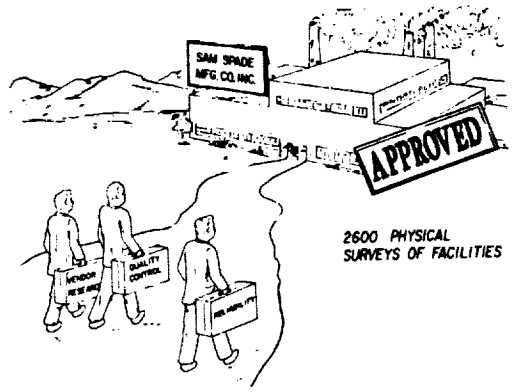
During the evolution of the Atlas/Mercury program we had some 9,000 sources available to us.

We utilized the services of 7,600 individual suppliers during the course of this program (Slide 1). We issue about 110,000 purchase orders per year. We utilize over 65 per cent of our supplier resources for repetitive purchase orders. Our suppliers are located in 43 states, approximately 65 per cent of our procurement activities are centralized in the western part of the United States, 25 per cent in the central and middle region and approximately 20 per cent on the east coast. Over 50 per cent of our sales dollars are spent with our subcontractors. Of the total number of resources that we have utilized, our Vendor Research and Evaluation Group has physically surveyed the facilities of over 2,500 individual fabrication-type suppliers (Slide 2). These surveys have been in coordination with reliability engineers and quality control engineers, as required, design engineers, financial experts and all those required on an as-required basis.

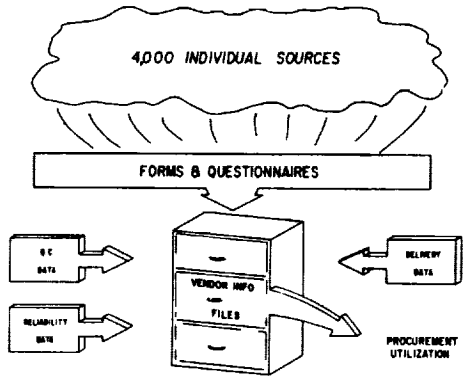


Slide 1

We maintain information relating to some 4,000 sources (Slide 3). We obtain a tremendous amount of data from these sources through the use of various forms and questionnaires. Unique documentation and data has been prepared relative to over-all supplier management, quality control, financial, organizational, and reliability activities. We now have this data compiled in a data retrieval system where we can select some 10,000 characteristics, we can produce a source capable of producing supplies in five minutes.



Slide 2



Slide 3

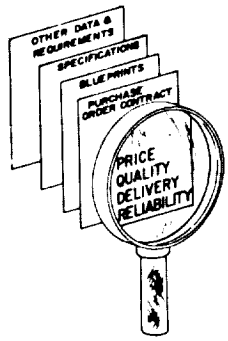
Detailed information is also requested from our sources relative to special testing, environmental applications, design reviews, value and improvement analyses, special research and development activities and reliability studies undertaken.

In its broadest sense vendor evaluation is a generic term. Actually it encompasses many factors, all of which assist us in our search for reliable sources.

By this slide we attempt to indicate in our purchase order contracts the reliability requirements, quality control requirements, specifications involved, whether processing or manufacturing (Slide 4). So really communication becomes a paramount consideration.

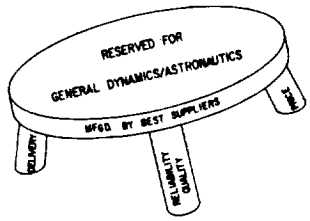
Naturally we rely on our suppliers from a three-legged point of view. We saw the triangle this morning in the presentation by our keynote

speaker in his opening address (Slide 5). I prefer to look on it as a three-legged stool because you can have a supplier who is always on schedule, low in cost; but if on schedule and low in cost, and he isn't reliable, then we can't sit on the stool. So all three legs must be utilized.



Slide 4

Now, the above-described evaluation processes are utilized in the initial selection of our suppliers. This function is administered by the Procurement Department. This initial selection of sources is only the foundation upon which the Reliability and Quality Control Departments of Astronautics build their source data.



Slide 5

Our reliability and quality control functions maintain data relative to components and assemblies, fabrications, corrective actions required and acted upon, and provide a means for statistical measurement programs for each vendor's reliability and quality control performance.

In setting the stage for this particular seminar, it is extremely important to note that General Dynamics has since the inception of the Atlas weapons program per se maintained a vigorous program of vendor source selection and evaluation. Because of our efforts in this regard, little modification to our supplier reliability programs was required to produce the Atlas/Mercury vehicle. We found that our efforts at the outset of the program were extremely rewarding in the final performance of our Atlas vehicles. As in all research and development space endeavors, reliability is a concept towards which we must all work. Reliable suppliers must

be developed as the tasks evolve. As engineering and fabrication concepts change, so must the reliability pattern change.

As we are all aware, reliability as such should be designed into any given component or assembly. True reliability can only be achieved through endless, frustrating and sometimes heartbreaking testing of individual components and assemblies and through individual efforts and educational processes. Reliability cannot be achieved solely by the prime contractor. Immeasurable amounts of communication, motivation, coordination, and cooperation between the prime and the subcontractors are needed. Reliability is everyone's responsibility.

Our panel is comprised of representatives from the United States Air Force, our associate contractors, our subcontractors and members of our own GD/A family. Each of these individuals are experts in their own field of endeavor and are exceptionally well qualified to discuss their respective topics.

I turn it back to the Chairman.

COLONEL BRANDEBERRY:

I am sorry I failed to introduce myself at the beginning of this. I am Colonel Brandeberry from the Space Systems Division, and I am a director of the Atlas Space Launch Vehicle there.

The next talk will be by Mr. L. I. Medlock, who is manager of Quality Control for GD/A. He is responsible for quality control inspection of procured materials, electronic and mechanical products, including spares acceptance and delivery. He will talk to you on vendor selection and controls.

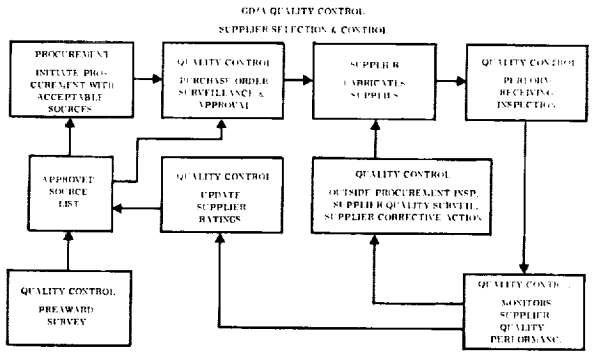
Mr. Medlock.

MR. MEDLOCK:

Thank you, Colonel.

In the Astronautics Plan for supplier selection and control, one of our primary controls over supplier quality is to limit procurement to approved sources.

I have a flow chart that depicts the flow of activities and information from supplier evaluation by our quality control engineers through the entire cycle back to updating the supplier performance rating (Slide 6).



Slide 6

Potential suppliers are surveyed by quality control to determine their potential capability to produce quality items.

Results of the survey are evaluated and those indicating a capability are added to our approved sources document.

The approved sources document is used by our purchasing buyers to initiate the procurement with approved sources. It is also used by our quality control purchase order review group to audit purchase orders to see that we are procuring from approved sources.

Purchase orders are reviewed by quality control to determine that we have included our total quality requirements of the purchase order.

Suppliers performance is monitored, as you will note on the chart, by our source inspection, Supplier Quality Control surveillance personnel making visits, and by the results at the receiving inspection level, which is really the proof of the pudding -- acceptance or rejection at the receiving inspection level. This is the key to a supplier performance rating.

Now, in the area of corrective action, which is one of the topics that I was to mention here, we have a formal corrective action program where we submit a vendor corrective action form to the supplier. However, we have found that this must be supplemented by letters, phone calls, and personal contact and our experience is that there is no better method than personal contact. We find that we can resolve our problems through

mutual discussion much faster than we can through exchange of forms and paper work.

We have found that in some cases where gross deficiencies are noted, a new quality control survey is required; this is primarily because many times we find that we have changed the type of item that we are procuring. Something has not been added or something has been lost in the change, and as a result, a new survey will pick up the particular point of deficiency and through mutual discussion we can resolve that problem.

Also in the area where we are having extreme difficulties, we add our own procurement source inspection to the purchase order. We have found that one of our quality people in the supplier's plant can often help resolve the problems that have caused the need for corrective action.

If in the final analysis after vendor conferences, with purchasing, our engineering quality control, everybody present, we find we cannot correct the situation, then, of course the supplier is removed from our approved sources document.

An outgrowth of our experience has indicated that a post-award survey, -- a survey after the capability survey, where you go in while the hardware is being produced and take a first-hand look at step-by-step, in-process activity and point out those areas of deficiency, hold an exit interview before you leave with the supplier and give him an opportunity to understand the specific points that you are making -- have been a great help to us in resolving supplier problems.

We found again that the face-to-face contact and mutual exchange of ideas and information has been very helpful to us in resolving our problem. We think our batting average is better at this point in time and the realization of our objectives has improved.

Gentlemen, this has been a very quick review of Astronautics' plan for supplier selection and control.

This ends my remarks. I would be happy to answer your questions.

COLONEL BRANDEBERRY:

Gentlemen, the floor is open to any questions that you may have in regard to Mr. Medlock's presentation.

Please state your name and organization, please.

MR. BRUCE:

Paul Bruce, Lockheed, Missiles Inspection.

How large an organization do you have for your vendor selection and your outside inspection?

MR. MEDLOCK:

We have roughly 60 employees in our outside inspection activity and approximately 30 internally who perform purchase order surveillance or review and do the supplier evaluations, process the corrective action requests, and coordinate that activity.

MR. BRUCE:

Thank you.

COLONEL BRANDEBERRY:

Right behind you.

MR. NICHOLS:

Willard Nichols of Hughes Aircraft.

I would like to ask you what your policy on the Mercury project in particular has been on raw material procurement on -- well, specifically do you accept supplier certification or do you do in-house test as well?

MR. MEDLOCK:

We require both on all raw materials, certification and our own material verification laboratory test reports. Material is held at the receiving inspection hold area until the test reports are completed.

COLONEL BRANDEBERRY:

This gentleman here (indicating).

MR. BUCKLEY:

Buckley, Douglas.

Your own material in-house verification -- is this on a 100 per cent basis, or an audit or check of the test reports?

MR. MEDLOCK:

It is both, I think.

Sam, can you help me?

MR. BRAUN:

As I understand your question, it is on a 100 per cent basis to the extent that material in each lot is verified by taking a sample from each lot. In other words, once we accept a lot from a supplier, this doesn't mean that from this point on all subsequent lots from the same supplier are accepted on the basis of the first lot.

MR. BUCKLEY:

By "lot" you verify his test report at 100 per cent by a "lot"?

MR. MEDLOCK:

Yes.

COLONEL BRANDEBERRY:

Over here (indicating).

MR. GRADY:

Bill Grady, Aerojet General.

For the Mercury program did you have any special controls other than normal for Atlas for vendor selection?

MR. MEDLOCK:

No, sir. We had five components that were restricted to a selective basis to procurement from a single source and then there were a number of components -- this will be talked about in the afternoon session on testing -- but there were a number of selected components for the Atlas-Mercury booster, but there weren't any special surveys made.

MR. MacCARLEY:

John MacCarley, Northrop Space Laboratories.

I wonder if you could elaborate a bit on how reliability is integrated into your corrective action cycle, particularly with regard to failure diagnosis or failure analysis?

MR. MEDLOCK:

Yes, I think I missed that point in my talk.

Normally, corrective action requirements are: rejections at receiving inspection; subsequent rejections during fabrication, assembly or test; and from failures from the test site or the launch site being fed back and through failure analysis.

We had a formal failure analysis program throughout the Atlas-Mercury project and information from failure analysis reports indicating that corrective action requirements at suppliers were fed through our formal corrective action cycle to the supplier.

In many cases our suppliers were called in to participate in the failure analysis. In other cases, the part was returned to the supplier for him to supply the failure analysis with our people present.

MR. MOORE:

Colonel, one other point we might make in that same area is that we had a requirement in the Mercury program for effective corrective action or at least identified because of failure and we had stop-gaps, as you might want to call them, in that the acceptance of the next booster was essentially predicated on a successful analysis of the cause of failure and an indicated corrective action before we went a little farther.

I think this made the system very responsive and we feel that it also contributed materially to the success of the program.

COLONEL BRANDEBERRY:

This gentleman over here (indicating).

MR. WALTERS:

Walters, Airite Products.

You stated in your talk relative to the purchase order review and approval that the quality control personnel reviewed the quality control requirements. In your organization, who establishes these requirements and who supplies the order and to what scale do they follow the orders?

MR. MEDLOCK:

Well, actually the requirements are established primarily by engineering and then quality and reliability requirements are added. Contractural requirements that are reflected in our over-all specifications generally are automatically included through engineering release. However, we have requirements such as determination as to whether or not we will require our own source inspection, whether or not government source inspection is required, whether or not testing will be accomplished at the supplier's plant or at our plant and to what degree. A number of these things are information that is known. There are also a number of

check-list items that our purchase order review personnel look for on every purchase order.

MR. WALTERS:

In other words, each item has its own check list of requirements placed before placement of orders?

MR. MEDLOCK:

Not in all cases, no, but hopefully we get through there.

COLONEL BRANDEBERRY:

Gentlemen, I am sorry, we are going to have to go on. I know there are still a lot of good questions, but we are limited in time.

MR. MEDLOCK:

I'd be happy to talk to you on the side here during lunch or any time.

COLONEL BRANDEBERRY:

We still have a ten-minute over-all question period coming up here.

I would like to introduce at this time Sam Braun, Chief of Inspection for Procurement at the airframe contractor.

Mr. Braun participated in the Atlas program since its inception. He has held various quality control supervisory positions in all phases of the quality control program. Prior to his present assignment he was the quality control administrator for the Atlas program.

He will give us a discussion on supplier seminars.

Mr. Braun.

MR. BRAUN:

In reviewing the Mercury pilot safety program we recognized the need for giving some attention to the subcontractors and supplier activities.

Since a large portion of the contract dollar is expended in outside procurement, it was obvious that a proportionate share of our efforts to upgrade reliability should be directed to these areas. With this in mind, we planned to carry our message to these people through a series of seminars.

Of necessity we had to be selective in a choice of the several thousand suppliers who were participating in the Atlas program. A determination was made that this selection would be based upon the complexity and application of the parts supplied and on the uniqueness of design to the Atlas program.

Two seminars were scheduled; one was held during the latter part of 1959, and the second was held during the early part of 1960. Approximately 100 supplier representatives were in attendance and they were equally divided between the two seminars.

In any discussion with subcontractors it is only fair to consider added costs when discussing added task. Therefore, it was important that it be made quite clear to these representatives that we are not talking about added task. Our primary objective was to impress upon them the essential philosophy of the Mercury pilot safety program of "Do Good Work."

We asked that the suppliers initiate within their own organizations a program of motivation with this theme in mind. We also asked them to convey the same message to their own suppliers. We hoped in this manner that we would reach a greater number of people in the industry beyond those who were in actual attendance at the seminar.

The contents of the meeting included the following: statement of the objectives of the program; a pictorial presentation of the Mercury booster and the McDonell capsule with an explanation of the Mercury man-in-space mission; a resume by the section heads of our own quality control organization which outlined the manner in which the Mercury

pilot safety program was being implemented within our own organization; a discussion on human aspects of reliability; and the presentation of a reliability film "On Target."

At the completion of the presentation a brochure which included an Atlas fact sheet was passed out to the participants.

Photo coverage was made of the meeting and copies of these photos were subsequently mailed to each of the participants. They were also informed that representatives of GD/A were available for presentations in the supplier's organizations and the film "On Target" was also available for their use.

It is very difficult to measure quantitatively the results of these seminars. However, we were encouraged by the enthusiasm of the participants and the responses that resulted from the program.

In retrospect, it is my feeling that the undertaking was perhaps a little on the conservative side.

Profiting from this experience, we recently held a series of supplier seminars as a part of our Space Launch Vehicle Reliability Program. These seminars reached some 600 suppliers over a period of five individual sessions. We feel that any technique that brings the prime and the subcontractor closer together in realizing a common objective is worthwhile and should be continuously pursued.

Now, if anybody has any questions at this time, I would be happy to try to answer them.

MR. BUCKLEY:

Buckley, Douglas.

Did you make any effort at all to try to measure quantitatively the effect of your seminar? Were you able to notice any reduction in rejections or anything like that over a period of time?

MR. BRAUN:

No, we did not.

However, in selecting suppliers, I didn't mention this fact, but each of the suppliers had shown a successful quality history in our Atlas program previously, based on our existing quality performance rating program.

MR. MEDLOCK:

I might add also that during this total time period there has been a continuous improvement in our quality trend at the receiving inspection level.

COLONEL BRANDEBERRY:

Yes?

MR. GRADY:

Bill Grady, Aerojet.

Of these 100 suppliers, approximately what percentage of the procured parts did they represent? In other words, how big a portion of these 7,600 vendors, which, naturally, may not represent that they get all the parts, but how much of the parts? Do you have any idea?

MR. BRAUN:

Well, I am afraid I couldn't even hazard a guess at this time what they represented percentagewise of the total hardware complement. However, as I indicated, they did represent those suppliers who were providing hardware that we considered unique to the Atlas application as opposed to suppliers who were supplying the so-called proprietary off-the-shelf type items.

MR. MEDLOCK:

And generally I think the suppliers who were invited were those furnishing items under specification control or our GD/A book specification control as opposed to piece parts and raw materials and that type of thing.

MR. BUCKLEY:

When you got into the Mercury program was any effort made or did you come up with any way in which to try to upgrade any off-the-shelf type items?

MR. MEDLOCK:

I don't know whether the term "upgrade" is the right term. However, there have been occasions.

MR. BRAUN:

And I am sure all of you are familiar with this -- where off-the-shelf items are used or modified for a particular application on a program.

MR. WISHENGRAD:

Howard Wishengrad, General Electric.

Mr. Medlock, have you had any problem where you had lead time from approved sources that were too long to be useful?

MR. MEDLOCK:

I think I could tell you in all sincerity that every problem that has ever existed in anybody's activity, we have had it, including that one.

MR. WISHENGRAD:

What was your solution in this case?

MR. MEDLOCK:

We have done all kinds of things. This problem hasn't gone away; we have it right today, and I think again primarily our solution to it, if it is a solution, has been through working together with the supplier because there just isn't any substitute for that, helping him to help us.

MR. WISHENGRAD:

And one other question -- I am trying to sneak in a double-header -- what about proprietary items where the vendor or supplier is hesitant in giving out information where you have had failure or difficulty in handing him a list?

MR. MEDLOCK:

Well, again I think it is a matter of developing some kind of a mutual interchange of vital information and for some of it I think you have to finally withdraw and say, well, if I can't get it I can't get it; but I am going to get all that I can get and based on that I will arrive at a conclusion as to whether or not I can make it without the amount of information. If I can't then maybe we have to go the legal route or some other route and get the government to move in and help us get the information we need.

COLONEL BRANDEBERRY:

Gentlemen, to go on here, I would like to introduce Mr. D. E. Moore, who is a representative from the Air Force plant organization here.

Mr. Moore has participated in the Mercury program since its inception as Deputy Chief and subsequently as Chief of Air Force Quality Control.

In his present position he is responsible for contract compliance in the fields of reliability and quality control for all Air Force and NASA programs at this facility.

He will talk to us on customer interest and controls.

Mr. Moore.

MR. MOORE:

Thank you, Colonel.

Good morning. I would like to invite your attention for a moment to the chart that Mr. Medlock used.

We had an ECP on this chart last night. You will notice the arrows. They were red yesterday. We felt that this might be misconstrued as an indication of red tape rather than one of a dynamic management system between us and the contractor.

The first block that I would like to discuss for a second is the one which indicates our function of surveillance of purchase orders in government source inspection authorization.

You will also note that we conduct an effectiveness audit of the contractor's receiving function and finally we have an audit and an analysis function, through which all of the data that Mr. Medlock has discussed is processed to create a closed-loop system back again to our surveillance function.

Control of items purchased from suppliers is of utmost interest to us as representatives of the government. These items require as much or more attention as those items being produced in plant for two reasons: the length of the communication line and the fact that the individual reliability of each procured component contributes equally with all others towards reliability of a completed Mercury booster.

Items which were procured for the Mercury were processed to essentially the same procedures as supplies purchased for the weapons system. One exception was that many Mercury components were selected from the total population of those components for optimum or mid-range parameters and, of course, we had the other exception which was that any with a significant failure history or noted anomalies were also excepted from the program.

Within our organization, as I mentioned a moment ago, we have set up a function to review contractor's purchase documents predicated on the establishment of an acceptable quality control system by the contractor in compliance with Specification Mil Q-9858. This system provides procedures to assure that supplies purchased from vendors conform to contract requirements.

To measure the effectiveness of the contractor's quality control system and to authorize GSI, we review purchase documents for some of the following things:

We look to assure the inclusion of all applicable contract requirements. These include things from such mundane characteristics as proper marking and indication through the gamut of the inclusion of quality assurance and reliability requirements.

We also look to assure that we have proper vendor selection, that the vendor rating system is working, and that we are procuring from vendors who have a good performance history.

We look also to assure that adequate communications, including instructions and data performance, are included with the purchase document, and finally, as I mentioned before, we look to assure for government source inspection and to authorize it as it is required. We maintain close control of this particular aspect because we want GSI where it is needed, but only where it is needed.

An effective corrective action system is of utmost importance in maintaining good quality supplies from vendors.

We monitor the vendor corrective action system to assure that corrective action is accomplished in a timely manner. We are interested in seeing that there is adequate and expeditious feedback of discrepancy data and also to identify adverse trends.

We perform a normal material review board function to maintain control of departures from requirements for vendor items. Pertinent information is submitted through the contractor on vendor information requests. These departures are handled in the same manner as any nonconforming material within the normal operation of a quality control system.

Finally, for the purpose of emphasis on communication, we coordinate with government representatives at the vendor's facilities when there is a problem. This communication, we feel, is vital and necessary to assure that the facts are known, that the problems are identified, and that we get expeditious and timely corrective action.

In summary, we feel that for vendor selection and control we need good planning and we need discipline. Discipline, gentlemen, is very essential on a program such as this.

If any of you have any questions, I would be happy to answer them.

MR. WISHENGRAD:

Howard Wishengrad, General Electric.

You talked about bad performance history and selection performance. Did you ever on Mercury run any tests where they deliberately ran tests upon tests on these parts, using this as a culling-out process?

MR. MOORE:

There was a program identified as a "Search for Critical Weakness Program," which was one essentially for conducting tests such as you described, where components were tested, first, to the design level essentially, and then to higher incremental steps. This information was then fed back into the design and resulted ultimately in a better balanced product as far as the design parameter is concerned.

COLONEL BRANDEBERRY:

I'd like to add one comment to this, if I may.

In the Mercury program those selected items were not high or low on the scale. They were always nominal. So when each of these Mercury parts received a stamp that you have seen and the emblem that you have noticed, it was within the nominal area.

MR. BUCKLEY:

What was the nature and extent of NASA's activity, either paralleling or supplementing your activity in plant and with vendors?

MR. MOORE:

In the Mercury program not very much. The Mercury program essentially was pretty well down the road and was controlled with 9858, 550, and 520 and the standard Air Force specifications.

MR. WISHENGRAD:

You mentioned control of pieces. How did you verify that a vendor or supplier wasn't changing their processes either for the better or for the worse?

MR. MOORE:

That was a tough one. Sometimes we found it after it happened.

Generally the contractor has a data requirement system which he imposes on his purchase order that requires an identification of such changes from the major suppliers and vendors.

MR. BRUCE:

Paul Bruce, Lockheed.

The Air Force on the Mercury program, did they approve the special processes of the vendors or did the contractors do this?

MR. MOORE:

It was handled in a normal manner in force at that time.

MR. BRUCE:

There has been a change. What happened after the change?

MR. MOORE:

The change did not affect the Mercury program.

COLONEL BRANDEBERRY:

Gentlemen, at this time I would like to introduce Mr. W. C. Hargiss, Manager of Quality Control, Liquid Rocket Division of Rocketdyne, who is representing one of the associate contractors involved in the Mercury program.

He is responsible for all quality assurance and inspection functions for the Atlas booster propulsion system.

He will give us some comments on the relationship to GD/A and their own efforts in the military program.

Mr. Hargiss.

MR. HARGISS:

Thank you.

During the last 15 years the posture of quality control has changed significantly. We are today dealing with complex systems. We have lost the production runs. We are dealing with small samples. The cost of the hardware has gone up significantly, and as a result of this the necessity for a truly preventative program has become more urgent and we look at our supplier seminars, our supplier survey programs, and our constant communication with suppliers on an individual basis for complex items to help give us a better potential for a supplier to do a good job, and we look at our supplier rating system to measure the effectiveness or the performance of this supplier.

But at Rocketdyne we feel that the key link between the evaluation of potential and the measurement of performance is the inspector. We feel it is important in the area of sophistication that we live in today not to forget the man in the shop who puts his acceptance stamp on the hardware, and I would like to dwell just a few minutes on this because we feel it is very important.

Your rating system is no better than the data that goes into it and the whole purpose that we are trying to seek here by an information feedback, by looking at the hardware, is to get the quality into the hardware at the

point of manufacture, and that is right by the worker in the supplier's plant. So if your inspection system is not effective, all these other assists and tools and procedures do not approach their optimum value.

There are a few things that we learned at Rocketdyne during our association with this program that we think were real important.

We imposed upon our suppliers a requirement for them to record actual inspection results for critical components or critical characteristics.

Now, this is a relatively small portion of our over-all spectrum, but in looking through the total bill of material of our engine system, we selected what we felt were the truly important items and then the truly important characteristics and we asked our suppliers to write down what they found when they evaluated the hardware in their plant. They then sent this in to us with the hardware and then our receiving inspection function recorded their results right alongside the suppliers'.

We feel this gave us two significant benefits. First, we feel that it helped us immensely in transferring the responsibility for product inspection to the supplier because the better job he does in looking at the hardware, the better off we will be as we go down the line. Second, we feel that it gave us an opportunity to provide for a good instrument-engaged correlation program.

If we appreciate, and I am sure that all of you gentlemen do, that after the supplier finishes his fabrication operations, the level of quality has already been laid out and that anybody that looks at this hardware after that point is performing the function of a policeman or a detective, he is trying to find out what the quality is. So the more we can put the emphasis back on the supplier, the less mistakes we will find successfully after that and the closer the hardware is to the drawing.

How do we satisfy ourselves that the inspector is performing an adequate job?

We do this in three steps. With our receiving and source inspection function we are measuring the effectiveness of the supplier inspection system. After the hardware is accepted by our inspection department,

we have a hardware audit function that takes the items off the shelf, and this is prior to delivery to the customer and we re-inspect and this is done by meteorology specialists. The results we find in this area are fed back as examples for both our receiving and source inspection people and to the inspection people working in the supplier's plant. Then there is the third function, and this is very important, and this occurs after the hardware gets into the field. In addition to the normal standard failure analysis programs, we send quality specialists into the field to look at the hardware, to look at the way the customer is handling it and to look at problems through the customer's eyes because many things that are subtle and unimportant to us when we live in our own forest within the factory take on a new perspective when we see it through the user's eyes.

So by hooking these links together we feel that we have learned the importance of strong inspection and that we must not lose this.

The things that hurt are the obvious mistakes and unfortunately the things that we get kicked with more times than not today are not the mistakes that are associated with the intricacies of the hardware but something that some poor fellow, if he had just used his eyes, he would have seen.

I leave you with two thoughts: Don't forget the importance of your inspection people and don't turn your back on the hardware after the DD 250 is signed.

Thank you.

COLONEL BRANDEBERRY:

Any questions?

MR. RELYEA:

Relyea of North American.

Do you actually inspect it twice when it comes in your plant in receiving and in the hardware audit, and are both of these a 100 per cent inspection?

MR. HARGISS:

For the critical characteristics, I am talking about something like 15 per cent of the hardware. These are the truly important characteristics, yes.

MR. GRADY:

Bill Grady, Aerojet.

On this particular inspection you said that you recorded by the suppliers' inspection. Is this the normal inspection stamp or is this the recording of a variable?

MR. HARGISS:

This is a variable recording. The stamp goes on the document. The stamp goes on the hardware. But we have listed these important characteristics and he writes down his actual inspection results, variable data, actual test results.

COLONEL BRANDEBERRY:

Gentlemen, I would like to introduce Mr. J. W. Cook, a representative from one of the subcontractors involved. He is Manager of Technical Support and Reliability Engineering in the Kearfott Division of General Precision, Inc.

He is responsible for the technical direction and planning of reliability programs on guidance subsystems and components.

Prior to the reliability assignment he was a project engineer in the gyro reference laboratory.

Mr. Cook.

MR. COOK:

Thank you.

Kearfott supplies the Type 2506 Floatograth Integrated Gyro for the Atlas-Mercury booster. Three gyros are used in the autopilot.

In discussing the Kearfott relationship with General Dynamics, the coordination with General Dynamics on the test results was a major area.

Data from environmental testing performed at General Dynamics was continually documented and transferred back to Kearfott for analysis.

The acceptance testing on gyros at General Dynamics were made to be an exact duplicate of the acceptance test at Kearfott. This was to ensure compatibility of the test results.

A General Dynamics quality control registered representative was at Kearfott at all times throughout the program.

Kearfott representatives in the area of STD had full access of all data at General Dynamics.

The corrective action cycle was an essential element of the program. Specific General Dynamics' forms accompanied the return of each gyro. One form indicated the expected trouble, another form indicated the operational and life history of a unit.

The Kearfott corrective action involved close coordination between project engineering and quality control.

On receipt of a gyro a service and repair order was filled out indicating suspected trouble.

Quality control people performed a failure and verification test.

Analysis of this testing indicated what corrective measures should be instituted.

A spin motor reliability program was instituted.

One out of every five motors produced was tested for a period of approximately 200 hours. A normal test would be 50 hours.

One out of every 25 motor and float assemblies was tested until it wore out.

On the basis of this program we were able to increase the service life of the unit to a factor of two.

The program for the Atlas-Mercury involved a recognition of the program goals. Importance of the program of the man in space and the fact that everyone contributes to the ultimate reliability of the unit -- this was handed down to our lower suppliers.

Gyros for the Mercury program were selected at General Dynamics based on performance characteristics.

The information generated from General Dynamics was continually channelled back to Kearfott and we had an up-to-date status. Also we cannot overemphasize the importance of personal contact.

Kearfott facilities were surveyed by General Dynamics' quality and reliability personnel.

Kearfott handed down the over-all requirements to our lower tier suppliers.

We manufacture the majority of gyro components. However, there are certain elements that we do purchase, namely heaters, thermostats, damping fluid, motor bearings, lubricants, electrical terminals, electronics, wire, and metal work.

We indicated our reliability and quality requirements in the purchase order by reference to particular practices and procedures of standard operations.

We have an established vendor control and evaluation procedure. This involves Kearfott personnel to make facility surveys of our suppliers.

We have an approved supplier list. We continually monitor incoming inspections. We provide certificates of approval for special processes. We have quality rating supports whereby a vendor's rating is continually established. We have deficiency reports whereby particular deficiencies are noted and we have supplier analysis resulting from the culmination of a deficiency investigation.

This essentially is a summary of the Kearfott relationship to General Dynamics in the Atlas-Mercury booster program.

COLONEL BRANDEBERRY:

Any questions of Mr. Cook?

Yes?

MR. RUSSELL:

Otis Russell, Honeywell.

You mentioned the spin motor reliability program. Was this part of the whole reliability program funded at Kearfott by GD/A or was this an effort that you were conducting on your own?

MR. COOK:

This was a program funded by General Dynamics to assure higher reliability in the units that were shipped.

MR. STERNBERG:

Paul Sternberg.

Were you held to a quantitative reliability requirement which you demonstrated, et cetera?

MR. COOK:

There was no quantitative reliability requirement in our contract. However, we did make estimates and supplied this information to General Dynamics.

COLONEL BRANDEBERRY:

Yes?

MR. NICHOLS:

Nichols of Hughes Aircraft again.

Did you come up with any sort of burned-in program to eliminate early-life failures? Did you examine statistics in that area?

MR. COOK:

Essentially the spin motor reliability program was part of the production effort. That is, one out of every five or one out of every 25 assemblies was tested. This is from production. So we considered the early failure periods the production prior to acceptance testing.

We did statistically analyze this and felt we had a greater assurance on the reliability of items that went through testing.

MR. WISHENGRAD:

How were the life limits from test time established on the gyros, for example? What kind of requirements were established on tests so you were assured that a flight gyro wouldn't be a worn-out gyro?

MR. COOK:

We had a fairly good estimate on the service life prior to the testing and the spin motor reliability program actually assured we were using reasonable limits.

COLONEL BRANDEBERRY:

Gentlemen, are there any questions that you have in regards to any portion that has gone on?

MR. RELYEA:

Relyea, North America.

First, did you have any numerical reliability requirements for any of the suppliers and second, how did you know that the part that was being supplied was reliable so that you could apply controls to this?

MR. MEDLOCK:

There were no numerical values assigned on anything to my knowledge.

I don't know if I really know how to answer the second part of your question myself. I don't see any volunteers.

There should be someone here in the crowd who could answer that question.

Dave?

DAVE ARCHIBALD:

Dave Archibald, GD/A

If I understood the question correctly, of course there were contract requirements concerning the targeting and the performance was estimated with the entire system. But as far as quantitative reliability requirements for each and every segment of that system, no, not initially in the program. In other words, there wasn't that numerical value assigned.

MR. RELYEA:

Was it finally in the program?

VOICE:

There was a number of studies, unofficial studies, I might add, to assess in these components and there has been a mathematical model

basically made -- the military representatives here are familiar with it -- but basically it was not only assigned to the vehicle itself, but also the AGE.

MR. RELYEA:

So you haven't been able to project anything from a reliability figure?

VOICE:

No, but we projected a lot of material from the performance.

COLONEL BRANDEBERRY:

I think I can answer that a little bit here. We are getting around to indicating this requirement by higher levels, every one of our particular contracts, which I am sure will have to filter down to the supplier, will have a numerical figure, and it is going to be coming down and you will see it in future contracts.

MR. WISHENGRAD:

Wishengrad, General Electric.

Mr. Dempsey indicated this morning that you used the preferred parts list in your dealings with the various tiers of vendors. How did you handle parts screening and secured parts as applied to the complex?

MR. MEDLOCK:

I think I have to be truthful in this area.

For many of the suppliers we did not have that control. However, this again is one of the evolvements from this total program that we see as a necessity and we are now getting into a position where can impose preferred parts requirements on our suppliers. But we have not been in that position before in total.

MR. WISHENGRAD:

Have you established any plans for this?

MR. MEDLOCK:

Yes, we have established a plan. However, our preferred parts program for the moment, the preferred parts list, total category list, is about 50 per cent prepared at the moment. So the program is not off the ground.

MR. WISHENGRAD:

Thank you.

MR. HARGISS:

May I add something to that, please?

COLONEL BRANDEBERRY:

Yes.

MR. HARGISS:

For Rocketdyne designed hardware that we give to a supplier to make, the preferred parts list is attached to the purchase order as one of our requirements for him to follow, and we expect him to maintain adequate records within his own facility subject to our surveillance.

In the area of a supplier proprietary design, no, we are buying his product.

COLONEL BRANDEBERRY:

Gentlemen, I am sorry, I will have to cut it off here.

I realize in this short time period you have not had a chance to make a thorough analysis of all that has been presented to you. However, I hope that we have stimulated your thoughts to the point where continued discussions will prevail on the subject.

Again I cannot overemphasize the fact or the importance of having reliable suppliers.

Thank you very much for your attention.

I would like to restate some of the things that are going on. From 12:00 to 1:30 will be lunch, and we go right out this door (indicating) and to the right of the swimming pool where the lunch will be served.

There will be three individual sessions after you return at 1:30.

After the three individual sessions, there will be a consolidated session in the original room here as you were originally set up this morning which will be a summary of all the panels and also I am told to remind you again that the social hour is from 5:00 to 6:00.

(Whereupon, this panel discussion was concluded at 12:00 o'clock noon.)

Subject Design Controls

Time 1:30 to 3:45 p.m.

Location Atlas Room

The design control panel will discuss Mercury-Atlas booster design techniques and review, product review, Air Force design surveillance, ASIS design techniques, and Aerospace Corp. surveillance. Panel members are:

Mr. J. Bailey, NASA, Chairman
Mr. M. Rosenbaum, Astronautics, Coordinator
Mr. P. E. Culbertson, Astronautics
Maj. C. L. Gandy, USAF
Mr. R. I. Kreisler, Astronautics
Mr. E. R. Letsch, Aerospace
Mr. H. L. Newman, Astronautics
Mr. J. W. Schaelchlin, Astronautics

MR. ROSENBAUM:

I am Mort Rosenbaum of General Dynamics. Our chairman today was to have been Kenny Kleinknecht, the manager of Mercury, and the NASA Manned Space Center in Houston. Unfortunately, he couldn't come. He had to cancel at the last minute due to serious illness in his family. However, we were very fortunate in obtaining a very highly qualified and capable substitute for Kenny, John Bailey, who will chair the session.

John is chief of the office of Reliability and Flight Safety at the Manned Space Center in Houston.

John, would you carry on, please?

MR. BAILEY:

The title of this session this afternoon is Design Controls, and with the six panel members to my left, we are going to start out by having them briefly discuss some of the highlights of the design controls that were used during the Mercury Program that contributed to its success, and also some of the lessons that were learned that are presently being used.

The purpose of the panel is to provide a springboard for discussions, questions and answers, that hopefully will result in ideas which could be applied to future space programs to provide more reliable vehicles.

I hope you will all feel free to participate and ask any questions you desire. This program is a fairly coherent package, and I think we will try to go through the whole package and then hold questions until the end; I am afraid that questions near the beginning would result in cutting off somebody's talk at the end.

Our first speaker is Mr. Howard Newman. Mr. Newman was the project engineer for Project Mercury, and as project engineer at General Dynamics/Astronautics he was responsible for all engineering aspects of the Atlas used to boost the Mercury capsules into orbit.

He will describe some of the general design techniques used during the Mercury Program.

Mr. Newman.

MR. NEWMAN:

As we discussed in some of the morning sessions, an Atlas D was chosen as the Mercury launch vehicle. The changes necessary to modify Atlas to launch a Mercury capsule were few and, in general, consisted of deleting those systems necessary for the Atlas weapon system and selecting and using only those systems on the Mercury booster that had demonstrated highest reliability and the most predictable performance. Only one system was designed for use exclusively on Mercury, and this, of course, was the Abort Sensing and Implementation System or ASIS. The techniques used in the design of this system will be gone into later by Mr. Schaelchlin. With only one new system on Mercury, it can be seen that our major task was not new design but control of the continuing design process so as to obtain the highest possible probability of success.

One step we took in this direction was to institute tight controls on the configuration. This control extended down to such details as requiring Air Force Space Systems Division and Aerospace Corporation approval of all changes, and I mean even minor liaison changes, on the booster and on the associated aerospace ground equipment.

This tight configuration control, of course, only supplied a baseline for design activity and, by itself, only prevented those surprises which can so plague the users of a complex system which is undergoing continuous change.

To attempt to smoke out those areas on the Atlas that still needed design action after the configuration had been frozen, we formed Tiger Teams, teams of systems specialists, which we called Tiger Teams, to review Atlas hardware and procedures in San Diego and at AMR. Mr. Bob Kreisler will go into the activites of these teams.

General Dynamics/Astronautics also implemented intensive failure analysis -- it was one of the things that really helped -- for all malfunctions of our critical functions involving the Atlas components so as to assure ourselves that no marginal areas were left uncorrected.

The Mercury program enjoyed the comparative luxury of existing concurrently with the large-scale Atlas test program. We took advantage of this by careful examination of the results of every Atlas test, and asking ourselves this question, "Can this possibly affect Mercury?"

If the answer to this question was, "Yes," a detailed investigation was undertaken by GD/A, by SSD, and the Aerospace Corporation. In every case the first consideration was given to pilot safety, and then to mission success. The ground rule we used was, if such a problem existed, corrective action had to be taken.

The solution of such a problem was again reviewed by GD/A, Aerospace and SSD, and if hardware changes were found to be necessary, these changes were programed for flight on several Atlas vehicles prior to introduction into the Mercury program.

This was done to obtain experience with the modified equipment without incurring the risk of a first flight on a manned vehicle.

I could go into a typical example of this process. We had an initial launch roll transient which was caused by various engine misalignments and roll torques on the booster. This became a problem when a statistical review of a large number of flights indicated the remote possibility of exceeding an abort-system roll-rate limit and thus causing an inadvertent abort.

The action taken by GD/A and the Air Force was to eliminate even this remote chance of failure as follows:

GD/A restudied all sources of roll torques, launch dynamics, and predicted the effects of these various things on the roll transient. Rocketdyne re-evaluated the test stand data on which we based our initial engine alignment.

Aerospace and the Air Force reviewed the results of these studies and directed that a change be made in alignment techniques and that an offset should be introduced into the zero positions of the engines.

It sounds like a big change but we shifted the position a tenth of a degree.

This extremely minor change was still programed into other Atlas flights and, in fact, was flown four times prior to incorporation on a Mercury booster. This change, as well as all other changes that received this careful attention, performed completely satisfactorily and generated no unforeseen side effects.

MR. BAILEY:

Thank you, Mr. Newman.

Mr. Phil Culbertson of Astronautics is our next speaker. As a chief project engineer for Atlas Space Launch Vehicles, Mr. Culbertson was responsible for engineering coordination on all Atlas launch vehicles, including those used in the Mercury program. He will discuss the design review techniques used in the Mercury Atlas program.

MR. CULBERTSON:

I'll start with my definition of design review, and I am not asking you to accept it except that I think it would be desirable to have a definition so that you can put in proper concept what I am going to discuss.

Design review, as it was employed in the Mercury program, is a systematic technical audit of engineering design by senior personnel independent of direct design responsibility. Within the scope of this definition, we found that design review could effectively be utilized as a very broad design guidance and appraisal tool.

Except with respect to degree and personnel levels, we did not employ any unique activities in design review in the Mercury program. The introduction of man into the program did, however, require a more conservative approach to design, as Mr. Newman has suggested, and motivated a review of the entire Atlas design and flight history.

Since one of the basic Mercury ground rules was to minimize new design except where the particular needs of the program required, we found that a review at the very beginning of a design change was effective, first in preventing the making of unnecessary changes, and, secondly, in assuring that the need, scope, specific direction and system interfaces of the change were thoroughly established.

The second time for an effective review we found to be between the 75 and 80% design-freeze point. At this time the concept is established, the bill of material is nearly complete, the reliability characteristics are analyzed, and the method and difficulty of fabrication have been considered. Also, at this time a minor change can be absorbed with minimum schedule and cost impact.

We found that in some cases, and for Mercury, in most cases, a third design review is fruitful to be held after the prototype is completed and subjected to evaluation testing.

If the previous reviews have been effective, the labor of the final one is comparatively simple.

Since design review is in some respects a policing action, the people assigned the responsibility must be senior men with seasoned mature judgment who hold the respect of the designers. We found that their effectiveness is enhanced if they are organizationally separate from the design groups up to the chief engineer level and if their charter is sufficiently strong that the recommendations of the review must be implemented or formally discarded in further deliberations.

Design review, we find, is a very logical time to consider producibility, inspectability, repairability, and testing requirements and parameters, and a multitude of other characteristics which the designer, fascinated by his specific solution to the design requirement, may have overlooked or slighted.

A seasoned team of engineers engaged in design review will therefore soon grow to recognize when they should call in assistance from the factory, inspection, or other personnel within the organization.

The number of reviews, degree of formalization, number and level of personnel involved must remain flexible and be suited to the nature of the problem to be considered. Although we have found that design review is not an inexpensive acitivity, because you must have senior people who do have the respect of the organization, no matter how comprehensive a design review activity, it is cheaper, faster, more effective and considerably more pleasant than post-flight failure investigation.

MR. BAILEY:

Thank You, Mr. Culbertson.

Our next speaker is Mr. Robert Kreisler from Astronautics. He now heads up the Product Review group, which is responsible for the administration and direction of the Tiger Team activities for the Atlas Space Launch Vehicles.

MR. KREISLER:

Thanks, John.

The aerospace industry has a language all its own with many strange words. One of these is tiger. A tiger has come to mean a senior-type man who has been around quite a while, who is a qualified specialist in his particular area, and has an inquisitive mind and asks questions why. These groups of people or Tiger Teams were sent to Cape Canaveral prior to the launching of each Mercury flight to make doubly sure that the flight would be a complete success. This type of organization was above and beyond all the normal, thorough, and critical checks that were formerly made by the field personnel.

A typical team operation would first review the configuration, the procedures, test results, and also any field or factory problems that may have been incurred.

Specifically, the paper is reviewed to make sure that the configuration is what is desired and that all changes have been included.

The procedures are reviewed for content and technical adequacy. Test results are scrutinized to determine whether there are any anomalies which might be indicative of a problem area, and, of course, the problems, both experienced in the factory and the site, are reviewed to make sure that adequate, thorough, corrective action has been taken.

After this review is accomplished, a walkdown or inspection is held and the missile is reviewed from top to bottom. Every visible piece of hardware is looked at.

If any discrepancies are noted, they are written down on a formal piece of paper.

The discrepancies are then reviewed to make sure that adequate corrective action has been taken prior to the flight, and at some time later all the discrepancies that may have been generated by this particular flight are again reviewed to come up with recommendations to eliminate this type of problem from recurring in the future.

One of the points that I think should be made here is that at all times reliability of the flight was of paramount consideration. At no time did management ever try to turn this Reliability-Schedule-Cost triangle in the other direction toward schedule or cost. Reliability was paramount.

As the result of this type of operation, many results were gained: an assurance of a successful flight, plus several other benefits. Among these were increased or improved communication. This type of situation put the senior designer, the expert, or the "Tiger" into the field with the field engineer who actually accomplished the work, who used his equipment; so this relationship bridged the gap of distance, time, and people, and resulted in an excellent exchange of ideas and problems and possible improvements for the system. In addition, as a result of these reviews, marginal and questionable areas were detected.

It was noted that the competitive spirit was also increased. Some of the people really outdid themselves to make sure the Tigers didn't find anything amiss in their systems. They didn't want anybody criticizing their area. They wanted to clean it up, and, of course, as a result of documenting these discrepancies, formal follow-up of these problem areas could be maintained.

As a result of these operations, a group was formed, namely, Product Review. The attempt was to formalize this type of operation and, in addition, to expand the operation not only to review boosters in the field but also in the factory, and also to review components prior to the time they were installed on the booster.

In summation, we have a group of senior people, experts, Tigers, whatever you may call them, who make a detailed scrutiny of the missile to give extra added assurance that this missile will fly and accomplish its mission successfully.

We feel that this has contributed to the success that we have had on the Mercury program, and we feel that we can recommend this type of operation in space programs where high reliability is required.

Thank you.

MR. BAILEY:

Thank you, Mr. Kreisler.

Mr. Schaelchlin from Astronautics is our next speaker. He is senior design engineer on the Abort Sensing and Implementation System and was responsible for the system design and testing. He will discuss the ASIS system, which is the only system specifically designed for the Mercury booster.

MR. SCHAELCHLIN:

Thank you, John.

As has been stated many times, the Mercury goal was not to design new equipment where it was not needed. It was pointed out that this system, the Abort Sensing and Implementation System, generally called ASIS, was designed specifically for this program. Its job was to protect the astronaut from catastrophic failure of the Atlas by sending an escape signal to the spacecraft when a booster subsystem showed marginal performance.

The film which we will see basically describes the operation of the ASIS. The discussion which follows will not be a technical description of the system but will highlight the major design and test considerations of this system and how the techniques discussed by the other panel members were applied to the program. This is how the Atlas abort sensing system works. (Film.)

MR. SCHAELCHLIN:

As is readily evident, the primary design requirement of the abort sensing system was to provide an abort command prior to any catastrophic failure. It was also designed so that a single failure of its own circuitry

would not generate an inadvertent abort, nor would this failure prohibit the system from operating properly should an actual booster malfunction occur. One pertinent step taken during the design phase of the ASIS was a review of previous Atlas flights to aid in determining the vehicle subsystems which were to be monitored. This was a continuing effort throughout the program, as was previously described by Mr. Newman. Another step was selection of components having high reliability and proven flight performance.

Failure mode studies were made to select components whose mode of failure, though unlikely, would be in a definite direction. A significant area of design coverage was the incorporation of design redundancy so that a failure of a component would not compromise the operation of the ASIS. An an example, two pressure sensors are used to monitor the Atlas hydraulic system. Since the failure mode of our pressure sensors is to the open circuit condition and the ASIS design requires that both sensors open the circuit to give a proper abort signal, the failure of one sensor will not generate this command nor will it inhibit this operation of the system.

Telemetry was used to monitor the system performance during flight. All of the pickup points were located within the control unit, but these pickup points were isolated from any of the operational circuits. This permitted us to obtain a detailed evaluation of every part of the abort system without degrading its reliability due to the extra components that would be required for telemetry circuits.

Throughout the entire abort system program, both formal and informal reviews were held with specialists of the Aerospace and Air Force agencies. These reviews covered all aspects of the design areas, such as parameters, components, circuits, as well as the various test phases. The benefits gained from these reviews aided in establishing the basis for the present design review activity at Astronuatics.

The time element between the start of the ASIS program and the first manned flight was not sufficient to gain the needed flight experience for the required measurement of reliability. An extensive reliability test program was conducted, in addition to the exhaustive engineering tests that were required for the development of the system.

Significant of this test program were the reliability life demonstration tests, where major components of the abort system were life-tested to determine the mean time between failure and to demonstrate the estimated reliability goal for the system.

Another significant test program was a search for critical weaknesses. Components were again tested to determine any design weaknesses. This was conducted in the same manner that had been used for components to be applied to other Atlas vehicles.

A limited amount of flight test experience was obtained before the ASIS operated in a closed-loop manner on the Mercury vehicles. Pressure sensors were tested on two flights and the complete abort system was flown in a piggyback manner on four vehicles. These flight tests permitted an opportunity to evaluate the operation of the complete system and its interactions with other Atlas systems in the flight environment. As a result of this effort, we were able to make several minor changes to correct problem areas that were not apparent during laboratory testing.

As with any new system, we sent responsible engineers from San Diego to AMR to acquaint the field engineers with the abort system. However, due to the nature of the program and its importance to the Mercury vehicle, responsible San Diego system engineers went to AMR to review the ASIS checkout for every major test conducted on static and flight operations. This was an effect of the Tiger Team activity that is utilized by Astronautics.

The people that were intimately associated with the ASIS program had the satisfaction of seeing the abort system perform as designed during all of the Atlas flights. In seven of the eight closed-loop flights, the abort command was properly generated by the shutdown of the sustainer engine after the system was disabled. The abort signal was properly sent when one of the pre-manned flights had to be destroyed as a result of a booster malfunction. The satisfactory operation of the ASIS on this flight was paramount for the capability of re-using the spacecraft.

MR. BAILEY:

Thank you, Mr. Schaelchlin.

So far we have heard from people from Astronautics.

Our next speaker, Major Charles L. Gandy, was deputy director of Launch Vehicles at SSD from June, 1960 to June, 1962 and director from June 1962 to the present time. Major Gandy will discuss the Air Force role in design controls. Major Gandy.

MAJOR GANDY:

Thank you, John. I believe the Air Force program office early recognized the need for an extremely critical design surveillance in all the aspects of the booster, and from surveillance inevitably grew the rigid control of which Mr. Newman spoke. The time period I am speaking of is the calendar year 1959 before configuration management /configuration control became the popular subject that it is today. I might say that during this time we were thought to be a little bit batty about the subject because the weapon system people did not exercise this kind of surveillance or control, although both weapons system and space launch vehicles now are subject to very similar controls.

Actually, the concepts that we had in our design surveillance were, first, the development of an extremely strong engineering capability in the aerospace program office to give an independent review of the Astronautics proposed changes.

Secondly, we required that each of the associate contractors give the full design picture the high-level management attention that has been described here today. This required personal attention from the highest levels in the companies.

Thirdly, we utilized the method of having technical review boards to monitor design changes. The particular board which I have in mind was formed as a result of the MA-3 malfunction. Upon completing its investigation of that malfunction, the board proved to be such a handy management tool that it was retained throughout the program under the title of the Manned Flight Surveillance Board, and this was primarily design surveillance.

Of course, the control itself was exercised through proper contractual channels, and later in the program it became apparent that certain

changes which had been authorized to the contractor previously without coordination could, in fact, be reflected in the over-all system unfavorably. This led to the control of which Mr. Newman spoke, requiring that all changes, both Class I and Class II, be reviewed by SSD and Aerospace Corporation prior to incorporation in the vehicle.

We believe in the program office that the tight surveillance and control has been a significant factor in the success of the Mercury program.

Thank you.

MR. BAILEY:

Thank you, Major Gandy.

Mr. E.R. Letsch of Aerospace Corporation is our final speaker. Mr. Letsch was assistant to the director and then associate director of the Mercury program at Aerospace. He was responsible for the pilot safety program and rollout activites. He is now an assistant director of the operation branch of the Gemini program for Aerospace Corporation. Mr. Letsch will discuss the role Aerospace played in the design controls. Mr. Letsch.

MR. LETSCH:

Thank you, John.

Like some of the speakers this morning, I will again have to use the word "we" in two ways. At times it will refer to the activity of Aerospace Corporation and at all other times to the activities of the entire Mercury team.

As Major Gandy pointed out, SSD and Aerospace, or at that time it was STL, decided very early in the Mercury program, when we established a pilot safety program, that we had to establish very strict controls on design changes. It was felt at that time that the Atlas vehicle was a fairly mature vehicle and that therefore very few changes should be required. The ones made during the course of the Mercury program were made primarily to improve reliability. In other areas some changes were made to provide redundancy where systems reviews revealed that

redundancy would be desirable. In some cases changes were made in design to ease the manufacturing and possibly avoid some human erros in the manufacturing process.

Now, a great many of the changes made were recommended by GD/A. In this case we at Aerospace then first asked the question, "Why?" and made an individual review of the proposed change -- the change itself -- as well as the effect of the change on other systems on an over-all systems engineering basis. We reviewed the proposed implementation of the change, and looked at the point in time at which this change would be incorporated into the vehicle.

In other cases we at Aerospace recommended that certain changes be made. Then GD/A asked the question, "Why?" and it was up to us to defend the changes or explain them.

Some of these changes, made as a result of failure analysis efforts, where it was obvious that something had been done, could occur almost any time in the program. We then had to sit down and think very carefully of when these changes should be incorporated on the vehicle during this assembly and checkout process.

There were certain points in time when we felt that the changes were incorporated after a certain amount of checkout, and that some of the procedures and checkouts had to be repeated again. At the last two specific checkpoints we had to again review the changes that were made, as well as the fact that they had been incorporated and properly documented. The first of these two checkpoints was at the factory rollout inspection, when we took delivery of the vehicle. Here the rollout team went over all the records of all the changes that had been incorporated on this vehicle to make sure that they were done properly and properly documented so that we knew exactly what the configuration of the vehicle was. The second check point was in the flight safety review at AMR prior to flight, where the same exercises were again repeated.

Several of the panel members have pointed this out before, but I think it is worth repeating. We were very fortunate on the Mercury program, inasmuch as all the changes that were made, especially the major ones, could be flight-tested on an Atlas test vehicle prior to the use of Mercury. Most of them had to be flown at least two or three times

before we allowed them to be flown in a Mercury vehicle. This is a luxury that I think a lot of manned space programs aren't going to have.

I have a somewhat uneasy feeling in my stomach in my new assignment when I think of how we are going to handle these things in the Gemini program, where the R&D test vehicles are certainly a lot more limited in comparison to the Atlas program. I think this was a very important factor that cannot be overlooked and again, as Major Gandy pointed out, we went one step further from what the weapon system did, and required that all Class II changes -- and some of those were very minor and very small -- had to be approved by SSD and Aerospace.

In carrying out such a requirement, this could delay the normal process of manufacturing quite a bit, having to go through a formal approval.

So in some of these cases the authority to approve Class II changes was delegated to the AFPR, and as far as SSD was concerned, and in Aerospace, it was delegated to our local representative at GD/A, so that on these minor changes very quick approval action could be taken, and at the same time we had this additional amount of control over these changes.

I think in general that is about all I could add to what the previous panel members have already brought out.

MR. BAILEY:

Thank you. That, I guess, concludes the formal presentation part of the program.

I think the floor is now open for any questions that you care to ask the six panel members.

MR. COLLINS:

Collins from Aerojet. Didn't your design requirements change when you introduced men into the program -- the safety factors of these requirements on propulsion system?

MR. CULBERTSON:

I don't know who you are looking to to answer that.

The question was, when we introduced men into the program, was there a requirement to change -- I guess the safety factor was the primary consideration that you had. The answer is no, and the decision was very deliberately established and published, with the exception that when we developed new systems, as in the case of the abort system, or where we were making significant changes, this factor was introduced into the design consideration. But rather than redesign the entire vehicle, which would have been necessary had we changed safety factors because man was introduced, we relied upon the experience we had attained by the time we were ready to fly it, and flew, as I say, in general, with the same safety.

MR. BAILEY:

So what is the requirement? Performance margins? I don't know whether he means performance margins.

MR. NEWMAN:

Every Atlas Mercury that we launched had a three-sigma probability or greater of making the mission. We weren't worried about performance anywhere near as much as we were worried about design reliability and fabrication. The main reason for this is fairly obvious, that on performance you can calculate numbers that you really have some faith in.

MR. BAILEY:

Are there any other questions?

VOICE:

I am impressed with the additional effort of flight testing, design reviews, product reviews, et cetera, and I recognize that this takes time and men, and I have been sitting here for two or three hours today trying to reconcile what you gentlemen say with what Mr. Walt Williams said earlier today -- that this need not be achieved with additional money or

additional time, and then I hear Mr. Letsch say that in Gemini, where you will not have the additional flight testing, he is concerned.

Can someone explain to me, what seems to be bothering me, how can you get this additional reliability without money and time?

MAJOR GANDY:

Let me take a crack at that, if I may. The first thing is, essentially, you get your flight testing for free because the flight testing is going on anyway. I think this is the first step. We didn't perform special Atlas flights to test these components, but because the weapon system and other space vehicles developments were going on simultaneously, we were able to get components aboard or changes cranked into the vehicles that were flying in these other programs. So this in itself was a tremendous saving, as we didn't have to pay for additional flight test programs.

MR. KREISLER:

I think one point here is that it is going to cost money for these activities, product review, design review -- all this extra surveillance costs extra money.

What I believe Mr. Williams was trying to say, that in the long run you will save money if you just prevent one failure. I don't think he was trying to intimate that it didn't cost any extra money.

MR. LETSCH:

I am sure that is what we all had in mind, and also, as far as the time is concerned. The two failures we had, this set the program back in each case about six months. We could have utilized perhaps the six months prior to the flight and done some of these things that we were doing later and possibly could have prevented a malfunction.

MR. CULBERTSON:

I think the difficulty in handling this kind of a development -- let's say, for this kind of a relationship -- is that you can't really predict how much a failure would cost either in dollars or schedules, and even if you

could it would be difficult for the contractor to discuss with the customer backwards, "Well, how would you spend this money that you won't have to use in case of failure to prevent a failure?" It is what is obviously a very difficult question.

VOICE:

Could I have one last question? Admitting this, are the prime contractors and subcontractors in a position to get this into their quotation, or is this additional cost negotiated later? If you are trying to be competitive and get your contracts -- I heard discussions from some of the vice-presidents this morning, you keep all of this at a very minimum. You don't even assume a failure. You don't even put into your quotations the cost of a fix, and you keep all your program management, review techniques at a minimum, in order to get the contract. But somehow you have to pay for this later. What confuses me is, how do you do this and still stay legitimate?

MR. ROSENBAUM:

I think there is a more receptive attitude on the part of contracting people in the customer's house today towards this sort of thing than there was a few years ago. I think we have all come to realize by contact with it that it is essential to have design reviews, testing, and so forth, to ensure the kind of reliability that we are talking about. They are more receptive to having this put in the work statement as part of the test.

When it comes to outguessing the cost of a fix, which no one anticipates -- that, of course, becomes very difficult, and that is the reason I think why the vice-president this morning said that you don't try to anticipate these, but you negotiate these as they come up. I think anyone who prices his proposal without a realistic look at this, I don't mean one that is over-board, but a realistic one, is only going to find himself in trouble later, should he win the contract, because he will be branded with this black mark that says he is in gross overrun.

MR. LETSCH:

There are some of the contracts that are now being negotiated by the Air Force on newer programs -- Gemini is one of them; it is written in the contract, a lot of these items that we have discussed today, like design reviews, failure analysis effort, quality assurance plans; in some cases, to quite some detail.

I think a contractor who has not gone through all of this may underestimate the effort that is required in order to do all these things for the first year of the contract, and then later find out that some renegotiating has to be done.

MR. ROSENBAUM:

I think as a last thought in regard to this particular point that should a contractor propose to bid a system in which he doesn't include this whole thing on a realistic basis, he will find, in my estimation at any rate, that the people who evaluate his proposal will rule him down for lack of understanding of the problem.

MR. BAILEY:

Any further questions?

MR. FRANKLIN:

Franklin of Hughes. I would like to ask Mr. Letsch a question: Certain times you spoke of a transition from STL to Aerospace and, in fact, on the Atlas program and on the Titan program, which you will be involved with in Gemini -- the STL organization still retains assistance engineers and engineering direction responsibility and has a lot of the design review responsibilities and technical coordination responsibilities of which you spoke, creating another management interspace that you haven't talked about here.

I would be curious as to how, in fact, you handle this within your own house and with the contractor when you have overlapping requirement between the manned system and the weapon system, where you have two systems, engineering and technical direction organizations.

MR. LETSCH:

I think basically Aerospace performs the systems engineering and technical direction role for SSD on their programs while STL performs this role for BSD. So there is a certain separation even within the Air Force along these lines. On a lot of the changes and problems that do come up for Air Force, STL, and Aerospace, we try to integrate them at meetings among ourselves; we get together and discuss these problems in a combined fashion.

When it comes to program peculiar items, then it is handled either by us or by STL, whoever the responsible agency is.

MAJOR GANDY:

I would like to add one point: the Manned Flight Surveillance Board that I mentioned was really created to overcome some of this difficulty, and we drew people from BSD and STL as well as from Aerospace and SSD and the associate contractors.

Just for precisely this reason, because we didn't want to, we could not afford to lose contact with the changes that were being made in the weapon system or the things that were learned.

We also for quite some time operated through the machinery of the weapon system configuration, but they still maintain coordination with the Weapon System Board, and of course we expect the contractor himself to keep us abreast and to keep his own people abreast of the changes in the two systems as they progress down the road.

COLONEL HOLLING:

I am Colonel Holling, deputy director for Gemini.

First of all, Aerospace performs a general system engineering and technical direction for the Gemini program within SSD. It is true that STL gets involved from time to time because of some of the problems that the ballistic missile program is having, and since STL is their general system engineer, providing technical direction, they work the problem for BSD, and in working the problem for BSD they quite naturally are working the problem for us too.

There is a coordination and cooperation between SSD and BSD, also, between Aerospace and STL, to assure that the fixes that are being proposed for the Titan II also meet the requirements of the Gemini program. So I don't think we can say that we have got two general system engineering director efforts going here. They are separate and distinct, although there is an overlap on common and mutual problems.

MR. BAILEY:

Thank you very much. Are there any other questions?

MR. BERDSTRON:

Berdstron, General Dynamics/Convair. From an engineering management standpoint, starting with original design, your various check points, your Tiger Teams, when failure does occur from an engineering standpoint, whom do you hold responsible?

MR. CULBERTSON:

Are you asking who is responsible to determine what the solution should be?

MR. BERDSTRON:

No. Whose responsibility is it for the initial error?

MR. CULBERTSON:

If I may answer that, there is no question in our minds but that the designer himself is responsible, the man who originally created the design, or his boss, and since I spoke of design review as an over-all policing activity, I could have said in this that at no time should the design review activity or any of these other things take from the designer the feeling that he himself is responsible for what he has created, and we at Astronautics attempt to make sure that that designer follows his idea straight through until it is launched, until the analysis of the data has been completed. We want him to be interested in what the factory is doing. We want to make sure that the designer himself understands that the factory is having trouble understanding it. We want to make sure that the inspector can inspect it and in fact does.

Now, of course, he is not responsible for that element of it, but he conceived the idea and it is his responsibility to follow all the way through.

MR. WEBSTER:

Webster of United Technology.

I am quite impressed with the Tiger Team concept and the fact that it is composed of specialists, and I recognize the advisability of getting your licks in early in a program.

My question is, if you have this talent available for Tiger Teams, why are they not turned loose on the design to begin with, and then they in turn accept this responsibility which we have just heard the designer has, as the information becomes available?

MR. KREISLER:

Your question is, why don't we use the Tigers to make the designs in the first place? Well, perhaps I didn't make this clear in my original discussion. These Tigers are the people that designed this. They are not in the group, Product Review. Product Review only administers and directs the program. They take these people, the designers, the senior designers, and organize them and send them down to Florida or the factory to look at their design.

Does this answer your question?

MR. WEBSTER:

Yes. I was under the misunderstanding that it was a separate group.

MR. KREISLER:

It is separate, the group is separate, and the only thing they do, in addition to what I mentioned, is that they do analyze. The Product Review group analyzes the problems and makes recommendations back to the designers or whoever may be concerned as to how to eliminate these problems.

MR. BAILEY:

The Tiger Team in your concept is a team that primarily is concerned with seeing that the manufactured hardware coincides with the design intent?

MR. KREISLER:

Yes. This is one of the things, yes.

MR. ROSENBAUM:

It is a kind of a forcing situation that requires the man who was involved in the design, as well as his boss, perhaps to go down and look at the actual application of the hardware represented by his design in the environment in which it was intended to be used, to the maximum degree possible.

MR. KREISLER:

That is right.

MR. ROSENBAUM:

So that he can see, perhaps for the first time, the relationship of that piece of hardware, the way it was designed, the way it was constructed, to the situation in which it was intended to be used.

MR. KREISLER:

That is a very good point.

MR. CULBERTSON:

The significance, I think, of a Tiger Team is that the activity is formalized and recognized as a formal activity.

Now, without this, one would expect designers to go out in the factory and see how his product is coming along and to look at the data occasionally, and if you could pry him away from the desk, go out to the field

occasionally. This is a forcing and formalizing function. Also, this followup activity makes sure that each item is finally closed out.

I might say that we have a similar concept in design review. I didn't bring up when I was discussing it, the fact that design review at Astronautics is not part of reliability. Reliability, rather, contributes to design review. The organization we call Design Review draws about 80% of the input to the review itself from other elements of the engineering or other departments within Astronautics. So it is a similar type of relationship to that which exists in product review.

MR. SUMMERS:

Summers, Rocketdyne.

I have a question for Mr. Culbertson. As regards design review, is it limited to reviews of component parts, or do you intend to extend your design review coverage to installation levels?

MR. CULBERTSON:

We go even beyond that, and we are quite flexible in this respect; for instance, we recently had a design review on a complete pod mockup, which involved many systems, electrical, mechanical, electronic, pneumatic, and hydraulic, as a matter of fact, and there was a complete review of that system.

Now, this followed reviews of individual systems, but this was on a new design. So we are completely flexible and go from the small pieces that you can hold on the edge of your finger up to virtually complete missiles, the boosters.

MR. KREISLER:

Design review takes care of the concept prior to the engineering paper being released; product review looks at the product after the design papers are released, so you have these two activities which are very similar in nature.

MR. CONTINA:

John Contina of Grumman. I would like to ask Mr. Newman a question with respect to configuration control, and to what level do you keep records of changes; in other words, do you really have a complete set of drawings for every configuration that you have fired, or do some of these configurations get lost as you make drawing changes, or do you just have a verbal description or a written description of the change rather than an actual pictorial? Could you go back now, for instance, after you have changed a number of boosters or made a number of changes in your boosters -- could you actually go back and from your drawings reconstruct one of the boosters that you have already changed?

MR. NEWMAN:

Yes. The information is available on our drawings. Once we have produced something and continued the production of that device or have used the device, it is never removed from our drawing itself. The reconstruction, however, of a particular configuration is a very time-consuming task because you have to start at the top and pretty much recreate what was on that vehicle.

We are in the process of automizing a large part of our engineering data records, and we will be able to essentially ask the computer systems to give us complete printouts. It can be done manually now, although it is a little time consuming.

Whenever we have had difficulty after a launch, we have had almost no difficulty going back and finding out what the engineering release configuration was.

MR. BAILEY:

Sometimes it might be kind of hard to get back to the details of the supplier parts.

MR. NEWMAN:

That is correct. We can get back to the level of what was called out on the drawing. If we did not distinguish on the drawing, say, between

two alternate vendors and if this was on a detail part that is below the installation log control, then we might not be able to tell who made that particular, say, transistor or resistor. We don't carry down quite to the level that the Minute Man Program has in serializing every resistor, every capacitor, every transistor.

MR. CULBERTSON:

I was tempted to make some statements this morning when we were talking about the reliability engineer, but felt it wasn't my business to. Mr. Ball had defined what that might be, and my definition was somewhat different from his, but I think that one of the disciplines of the reliability engineer which he has gained to a greater degree perhaps than the average design engineer will be a perceptive ability to analyze for potential failures.

Each designer himself should have this capability, at least to a degree. But I think that you can ask the reliability engineer to become somewhat more of a specialist in this area, and to some degree you can rely upon or lean upon the reliability group to investigate design from the failure predictive standpoint -- failure of mode analysis -- and here I am speaking to some degree of formal mode analysis -- and we ask this of the reliability group as one of their inputs into design review: what is the failure mode of this device which is being developed? Jointly, then, between the reliability group and the designer himself, it can be determined whether or not a change would eliminate a failure mode or eliminate the results of a particular failure through redundancy.

An an example of this ability -- perhaps to go into it somewhat more deeply on the part of the reliability engineer -- we have looked at several designs from the standpoint of redundancy in which on the surface it appeared that what was done for redundancy -- let's assume to some degree a circuit has been made redundant, and on the surface it appeared that this did in fact increase the reliability, whereas a detailed analysis by a specialist could show that this redundancy lowered the over-all reliability.

So this is an area where the designer himself must have some knowledge; as a matter of fact, we have had several seminar sessions where reliability people have discussed how to do failure-mode analyses, to refresh and bring it up in the mind of the designer.

This is an area where you can rely upon detailed specialists to give considerable assistance in time to bring this about, in design review, and also in daily contact between the reliability engineer and the designer.

We do our best to stimulate this kind of daily contact by asking the designers to seek assistance from reliability people, where they can go and by asking the reliability people to go out and look for trouble.

MR. WHEELOCK:

Ed Wheelock, North American, Space Division.

I have a general question for the panel: Do you feel that your reliability program on the Mercury system was adequate and, if not, what additional measures you feel should have been taken? In other words, what kind of advice do you have for those of us on Apollo?

MR. BAILEY:

You are talking about the Apollo launch vehicle, in general?

MR. WHEELOCK:

Any general thoughts.

MR. CULBERTSON:

Let me volunteer, stick my neck out a little bit. I don't think one could ever say that there has been sufficient reliability activity or that the reliability program was carried out to a sufficient degree.

There are several things I think I would say present technology would permit, whereas it was not possible a few years ago; several others which are not dependent upon technology but just dependent upon the development of the experience.

I think for one thing a good data center is invaluable to the reliability program, and I would be the first to concede that ours is not perfect. We have accumulated a tremendous amount of data in something like 160

Atlas flights now, and with all the associated testing which is going on. We have not optimized a system for making this data available and interpretable to the designer and the other people who would be interested and concerned with the data.

We have made a lot of progress in this area, but we have got some way to go, and I think that it is important to set up a system very early in the program before you have a lot of data so that you can handle the mass of data that you will be accumulating.

As a specific example, it is of considerable interest to the reliability engineer, and should be to the designer himself, to be able not to just look at the failures that occur on systems, but to be able to put his finger on the time which has been successfully accumulated on the system.

I doubt that any of us have had a good system yet for knowing how much good time we have. We have a lot of systems for knowing what failures we have. But the reliability engineer needs this other information.

I think in the case of the Mercury it was late in the program before we developed a really adequate failure analysis system.

Early in the program our comprehensiveness of our failure analysis with respect to the number of failures which had been analyzed and the rapidity with which we could analyze them was not nearly as good as it was at the end of the program.

The failure analysis, of course, must indicate not just what failed but try to get down to find out why it failed and how you can prevent it in the future.

If one can consider the human factor as part of the over-all reliability program, I think all of us have a lot yet to learn about how to eliminate human error, how to design so that human error is least likely to take place. In my opinion, design is a place to avoid human error. I think a lot of us have a great deal to learn in this area.

The title of people who are interested in human factors and human errors varies from human engineer to a lot of other descriptions, but

generally it is a poorly recognized and poorly understood occupation as such. As a matter of fact, the whole area of reliability is slow in getting a professional status, I think.

I tell my reliability engineers that they must for the moment consider that the designer looks upon poets, philosophers, musicians, and reliability engineers all in the same class, and I over-emphasize this because I want them to recognize that they have an educational program of their own.

These are a few examples, and I could certainly go on.

VOICE:

Let me be a little more specific: you said a couple more failures. Could you relate these back to something you didn't do that you maybe should have done?

MR. CULBERTSON:

We know specifically what the failures were. You are asking how we could have avoided this class of failure, I guess. Williams said this morning that one of them was, he believed it fair to say, a quality control problem, and I think in general we would agree with him.

The failures that we saw in the program, to the best of our ability, were not related to improper design from the standpoint of the design being able to do the job that it was supposed to do. To some degree, they could be related to the design -- making it difficult to manufacture so that the part would do it. As a matter of fact, I think if I were to say that there was one thing in the Mercury program which was related to the types of failures we had, it was a characteristic of the design which made it difficult either to manufacture or to inspect.

MR. LETSCH:

I would like to add a few words to what Phil has said. Failure analysis, you asked, is it adequate? That is the kind of question you can't really answer. I think it is never quite adequate. You always like to do it a little better. But the effort that GD/A has put in this area, especially at

the end of the Mercury program, I think, was excellent, and one of the major things that we felt was helpful was the thoroughness of the people in the failure analysis group. They never gave up. They kept on digging until they really isolated the cause of the failure right down to a tiny little component.

Second was the rapidity with which the loop was closed. The analysis was written up, corrective action was recommended and implemented. You can analyze all the failures you have until you are blue in the face, but if you don't come up with corrective action and do it fast, you can have quite a few more failures in the meantime.

Another thing, also; the failure analysis group of GD/A was in a position to write their reports and their recommendations without anybody putting the lid on it. They could write down the facts and recommend an action without regard to what this might do to the schedule, and it was up to the management people to decide what course of action should be taken. But they were not cramped in their style. They could put forth their thoughts and their recommendations. I think unless you have this kind of an organization setup the efforts of the failure analysis people can be stifled to a large extent.

MR. BAILEY:

I think I might say just one thing here in answer to Ed's question that I don't think has been mentioned:

On this business of making the failure analysis before the failure, it seems to me toward the end of the program there was a pretty determined effort in that direction and some pretty capable teams went through and screened all the subsystems in the vehicle to try and find any point where a single failure could result in catastrophe, and try to figure a way of designing around that so no single failure could cause this.

I think, in answer to your question, that is the thing you could do.

MR. ROSENBAUM:

There is another point too that we learn by experience, I think. Lots of times things will test satisfactorily either on a test stand, in a laboratory, or perhaps in a flight; that is to say, the end objective of the test will be realized, but there will be some peculiar perturbation or glitch in the operation which apparently had no effect on the total operation but was unexplainable.

Now, we found through experience and through a few hard knocks that it pays not to ignore these things. It pays to get back in and try to explain everything that doesn't work the way you anticipate it should work, even though the end objective of the test was realized.

If you don't, you may find on the sixth test you get the same glitch but now the test isn't completed, the operation isn't completed.

MR. CULBERTSON:

You can go even a little bit further in saying you want to determine -- if a system acts today a little bit differently than it did yesterday, even though the appearance of the system is that it operated completely normally each time, then you had better find out what happened overnight.

MR. ROSENBAUM:

Yes.

MR. CULBERTSON:

Because even though it is still within tolerance, something has caused it to change, and you may not know the complete story.

I would like to bring up a subject which maybe somebody from the audience can contribute to, because it is a fairly controversial thing, I think. We have discussed here self-appraisal by the contractor in design review and in Tiger Team review and the relationship of this kind of activity with the customer and the customer's agent, Aerospace.

I wonder if anybody in the audience has a comment to make about the degree to which the customer should survey the contractor as he makes his own self-appraisal. I may word it peculiarly here, but let's take a specific situation: to what degree should the customer participate in design review? On the one hand, if he does, he can be more aware of the degree to which the contractor is performing his job, and, on the other hand, his participation may inhibit to some degree the self-appraisal by the contractor and the ability of one man to look at the other man within the contractor's organization and say, "You didn't do your job," and let them battle it out at that point in the semi-privacy of the plant.

I have discussed this at various times with various people, and I don't know that there is any answer, but does anybody have a good suggestion?

MR. BALL:

Two comments on that area of discussion: my name was submitted to Aircraft Industry Association some months ago for comment. The comments were extremely vigorous along the line that the customer was over-invading the internal operations of the contractor. In this case I think a satisfactory interface has been established. It essentially says this: "every contractor must provide the customer with a full description of his own disciplines, his own management controls." It doesn't say, "We the customer say you must do this and you must do that." It says, "You must have such a discipline. You must describe it, and you must tell us." For instance, any one of us has a design review procedure. It says we must formalize it and we must tell the customer what our discipline is.

It then says that the customer participation will be that necessary to ensure that we are in fact following our own discipline.

I think the Air Force plant representative will develop more and more the responsibility and ability to ensure that each of us is complying with our own disciplines. That is one-half, I think, of the answer.

The other is this: the customer, to the extent the customer has his own experience retention system, let's say, the lessons that NASA has learned on Mercury, to the extent that they are smart enough to put that

into check-list form, then they have a positive contribution to make to design review on, say, Apollo because they themselves are equipped with their own particular experience retention. If they have nothing to contribute other than their biases and opinions, then I think that participation should be minimized.

But insofar as they have an effective, reputable experience-retention system of their own, we must make the provision for their participation. I think those are the two criteria.

MR. CULBERTSON:

The degree to which they need to sit in, let's say, sit in to determine that the contractor is conforming to the contract, I think, is the questionable area.

MR. BALL:

It is particularly this phase: in bidding for new jobs we commit ourselves to all sorts of disciplines, a wonderful quality assurance system. Our procurement people are going to be like this and that. We make all these promises when we are competing for new business. The customer has a legitimate need to see that we actually do the best of which we are capable -- specifically, what we promised in the proposal. To do that he has to sit in some design reviews to see that, in fact, we are following our own disciplines.

MR. BAILEY:

Does anybody else care to comment?

VOICE:

I can give you a specific example here on our O. A. O. which is being built for NASA, and NASA hired a consultant, Mr. Allen, to monitor Grumman, and at that time I was wondering what type of information do I give Mr. Allen specifically.

I was personally interested in getting an unbiased evaluation quite a few years back now, and I felt that if I gave Mr. Allen all of the reasons

and let him sit in on the design reviews and all this sort of thing, they would become participants; they would become involved in the design. So how do you get an unbiased evaluation? The decision here was, we gave them a description of the design. We answered all their questions. We showed them any drawings and any descriptions of what we had done. We did not give them our failure rates and numbers which we did our own evaluation, and so, based on this description of the design, I felt that they were able to come up with an unbiased evaluation for NASA quite independent of what my own group was doing. It was a parallel effort. You have got to be a little careful here, but -- of course, they made their recommendations with respect to design directly to NASA, but they did not sit in on design reviews when decisions were being made, and I think you can work out a relationship of this type.

We had a review some time ago where the customer was present, and I thought this was a little comical because the man running the design review specifically said the purpose of this design review is to give the customer visibility into the project, and I thought that was a rather good word. He was not trying to influence decisions at that time.

MR. CULBERTSON:

You will find, I assume, that by giving this data that they, whether they sit in the design review or not, they are contributors to the design decision, and they have the ability, and whether it is good or bad I am not commenting, but they do have now the ability to evaluate your design rather than you evaluating your ability to carry out your own disciplines.

So I think you are implementing, in my mind, that they are going considerably further than this process of monitoring your ability to carry out your contractual obligations. You find that this is so, or has it gone that far yet?

VOICE: I don't think there has ever been any question as to our ability to satisfy the contractual obligations. I think all companies that undertake a job of this type have this capability. I think the basic question here is, at any particular point in time, how do we stand with respect to cost, schedule, and reliability? And this is one of the prime objectives at the moment to evaluate. Are we going to meet our reliability requirements or not? And here an outside consultant comes in, and it can be the customer himself, "How do we stand with your design?"

I think that in most cases the customer is interested in as unbiased an evaluation as possible, and I think that an unbiased evaluation can only be given by somebody who is not emotionally involved in the decisions that have been made.

MR. McGINNIS:

McGinnis, Sperry.

Prior to your injecting this question to us, I was going to ask you a question in the inspection phase, for instance, we generally assume people are about 85% efficient, and if we want to get the 100%, maybe 600% inspection will get you there. I assume in design reviews you have independently, each would pick up something nobody else picks up and maybe get some kind of a curve. Do you have with this series of reviews that you had by Aerospace any ideas of the contribution of each? Is it a percentage of the problems the other fellow forgot, or is there one that doesn't really pick up anything? Have there been any statistics compiled on the relative benefit of each of these companies and customer reviews, and also do you see types of problems brought up by the customer that maybe we don't want to see in a company; in other words, maybe different types of things brought up?

This would be an interesting thing for us to get some speeches on.

MR. CULBERTSON:

We have never made any attempt to indicate exactly what each one of these reviews contributed. I think in general I would say that probably each one did contribute something; hopefully, each review in the series contributed less than the one before.

You always wonder when you go through this, and each time pick up a little more, how about the one we are not going to have? Would it have picked up something? That is where I guess management of the whole operation makes a decision that this is about as far as we will go.

I don't know that it is possible to say that Aerospace reviews or Air Force or NASA reviews picked up a category of things which we did not pick up, unless it is to say that they did force us to be more extensive in

our documentation in order for them to be able to review something; they had to have something to review, and it was therefore necessary for us to document it, and I think that that probably was a good thing in retrospect.

During this program we are more extensive in our documentation now in other programs than we were at the beginning of the Mercury program. I don't know. Maybe Ernie or Toby have a comment on whether they think that they found systematic kinds of things.

MAJOR GANDY:

I tend to agree with you. Hopefully, the reviews that have been made at SSD and Aerospace would not find anything. Again, you have the concept or the idea to use marked or unmarked police cars. If you have a marked police car, a lot of guys are going to quit speeding. If you have an unmarked police car, you are going to catch a few.

We hope from any of these things, by knowing there is another review, it is the same thing with inspections. By knowing that your work is going to be reviewed, you will put the extra effort into it. Whether this takes the form of additional contractor reviews, I don't know. I think there have been occasions when we have picked up significant items and, on the other hand, I think most of the design work is of extremely high quality, and you don't expect to pick up a lot of things.

Do you care to amplify?

MR. LETSCH:

I agree with what you say. We hopefully don't find anything, and I think at the end of the Mercury program when we have the factory rollout inspections some of the people at GD/A said -- I think they almost made it a personal crusade -- "I don't want this guy to find anything," and they would dig in even more to make sure that if there was anything to be found that they would find it. That is a good spirit.

MR. KREISLER:

I think there is one problem here, one possibility. People say, "Heck, if I miss this, the second team looking at this may find it."

I think this is something that we have got to be completely aware of and make sure, specifically, that these reviews don't act as crutches for other operations. It is a real problem.

MAJOR GANDY:

With proper feedback you eliminate a lot of that, I think. You eliminate that kind of feeling that somebody else is going to catch it.

MR. KREISLER:

This is one of the things we do with the Tiger Teams. We list all the discrepancies that we find, and we publish them to the man's supervisor, the department head, so that they can see it and do something about it. They have to be alert to this type of situation.

MR. BALL:

Ball, Boeing.

Traditionally, in the aerospace industry we have had what have been technology staffs. These have been staffed by high-level specialists who are not assigned to a particular project. For the purpose of this discussion, we can say they did three things. They developed the technology and prescribed this in forms, procedures to be followed by project people. They also took over particularly difficult problems. If, for example, in stress analysis there was a particularly difficult aspect to the aircraft, the technical staff would do that particular analysis. Then thirdly, they did run an audit function. We have used these non-project staffs, I believe, in this way.

The question is this: is there a danger today that we will go so far in putting all the Tigers on to the projects that we will undermine the traditional role of the non-project technical staffs?

MR. ROSENBAUM:

I think that danger exists, Dr. Ball. As a matter of fact, I think that as an organization we got into a little trouble in this direction ourselves over the course of the past year.

We have a very determined effort going on in our organization right now to revitalize this concept, and we are building up these staffs in what Jim Dempsey referred to in this morning's function as our functional engineering group to do just the things you described, to take on the difficult problems, to audit the operations of other people, to provide a core of advancing technology so that the people who are assigned to the project in their own specialty have an area of extremely highly qualified people that they can go to for help, that they can go to for future guidance and so on.

MR. SANDBERG:

Sandberg, Bell Aerosystems, Inc.

Another area question: we have heard that there were two failures. It has been explained to us that one failure was in the nature of a quality control problem and that we learned two lessons: that design could sometimes make it difficult to manufacture, or could make it difficult to inspect. Those are the two lessons from that one failure.

Could someone explain the nature of the second failure and the lessons to be learned from that?

MAJOR GANDY:

The second one was a structural failure. In time it was the first one. No one has ever satisfied all the parties concerned as to where it occurred, the interface area, either in the front end of the vehicle or in the adaptor between the launch vehicle and the spacecraft.

We didn't have sufficient instrumentation to properly determine the area of failure. We know a great deal about it, but the exact cause of the failure has never been fully explained.

We took an approach after that -- common certainly to the weapon system development -- of going at a number of things simultaneously, but primarily in the launch-vehicle business we strengthened the fore end of the Atlas, and McDonnell, who manufactures adapters, stiffened their adapters. We haven't had any similar problems. We, of course, went through a tremendous analysis that fall of 1960, using shake tests, wind tunnel tests, all sorts of analytical reviews, and it is a matter of personal opinion now as to what the failure actually was.

MR. ROSENBAUM:

Isn't it true, Toby, that we were all satisfied that the loads were higher than anybody had anticipated for reasons which we never did establish?

MAJOR GANDY:

This is true. That is why we actually went to the beefup -- stiffening the adapter and strengthening the fore end of the Atlas.

MR. CULBERTSON:

I think it taught us two very real lessons. Even in the age of space and ballistic missiles, aerodynamics is a very important consideration -- buffet, in particular -- and that perhaps insufficient attention had been given to that particular problem very early in the program.

The other one, which is perhaps a more general lesson that we learned, is that very definite and rigorous control must be made over the interface and the responsibility for the interface, and it is not possible to design up to a point and let somebody else design beyond that point. Somebody has to be responsible for going across the interface and considering the mutual interaction problem.

I think we learned that lesson, and I think that I have seen it in other space programs in which the Atlas has been involved, that there was an inadequate definition at the beginning of a program over the responsibility for the various things crossing the interface. We tried to make the Mercury interface between ourselves -- when I say "we" I mean the whole program management -- tried to make the interface between

the Atlas and the capsule as simple as possible in that it was made not at the staging interface but at a point where the adapter was bolted onto the Atlas.

The electrical interface was quite simple. The mechanical interface really was quite simple too. But I think we proved that the responsibility clear across the interface had not been adequately established.

MR. SANDBERG:

We really know what did fail, do we?

MAJOR GANDY:

We don't know what failed first. We don't know the exact cause.

I might expand on Phil's comment. Write your interface specs early. There was some question whether we were going to get the specs finished before the program was over or not.

MR. BAILEY:

These structures are large and flexible, and it is very easy for you to get inadequate clearance in there.

VOICE:

This had to go between the capsule and booster?

MAJOR GANDY:

Yes. On the model over there, that corrugated area is the adapter, and the two join together in the bolt circle just at the base of that, and the failure occurred somewhere either in the adapter or in the front end of the Atlas.

MR. ROSENBAUM:

This is under complicated aerodynamics pressure.

MR. BAILEY:

1,000 pounds a square foot.

MR. ROSENBAUM:

Conditions which are hard to simulate in the wind tunnel, and get a true representation of what does occur. So it is one of those things that no matter how carefully you may design and how much testing you may do, in this business you do run up against something that can only be proven by a flight test.

MR. BAILEY:

You can get into trouble if you have separation sensors which are supposed to detect separation, and they control the following steps in the sequence, and you don't have enough travel on them, so the structural distortions can set them off. It is a fairly common thing in the space program. You want to be very careful in designing any separation sensors that you make it travel a long ways before it acts.

MR. CULBERTSON:

Ridiculous things can happen which seem silly but at the moment cause quite an upset.

In one of our programs where the adapter was built by another contractor, they supplied the bolts which bolted the adapter to the Atlas, but for some reason -- I don't remember the sequence of events which led up to this -- we installed them. Well, at the launch stand in installing them -- and there are a sizeable number -- we stripped the threads on one bolt. We went back to the other contractor and said, "We need another bolt."

They said they didn't have any; it was our responsibility because we had stripped it. And this seems silly, but it happens that they didn't have any more bolts at the stand. It wasn't a hardware-type thing. This kind of thing caused an admittedly brief delay in the program, but it was one of the extreme frustrations. I don't know whether you can write in an interface agreement a solution to this type of problem. But it was an

interface problem which, if one contractor had been involved, responsible for the whole thing, it wouldn't have happened and wouldn't have caused the frustration that occurred there.

MR. NEWMAN:

We learned one other thing in the particular structural problem, and that is to attempt if at all possible to have adequate photographic coverage of the launch.

That particular launch was made in the midst of a driving rainstorm, and since we had no photographic coverage, we had to rely on telemetry. This later impeded the Mercury program many times, as you would hear about, waiting for good weather at the Cape or no clouds at the Cape. This became a ground rule of the program. We had to have excellent photographic coverage before we would launch.

MAJOR GANDY:

I don't think it is quite fair. I wouldn't have said "a driving rainstorm." There might have been one a little earlier. However, it was a cloud cover and there wasn't photographic coverage.

MR. BAILEY:

In Florida you can have a driving rainstorm in one place and 50 feet away, none.

MR. SUMMERS:

Summers, Rocketdyne.

I would like to direct a question to Mr. Kreisler.

Although less glamorous than a design review aspect, a procedural aspect, that is, the countdown procedure, the functional checkout preparatory to countdown: did you find anything in the Mercury program which might be applicable to the Apollo program and the necessity for regimenting countdown procedures, functional checkout procedures?

MR. ROSENBAUM:

I think I want to make this point: we are very rigid in our requirement that nothing gets done without a procedure, nothing, and there is no deviation from a procedure by an individual. You must follow the procedure completely. We don't change countdown procedures the night before a test or anything like that. We are very, very rigid and very determined in monitoring this aspect of the program.

If you want to add to that, go ahead.

MR. KREISLER:

We did find out that if there was non-adherence -- this is as to the weapon system program -- that most of the problems that the people encountered were because they did not follow procedures, and right now we are busily reviewing the procedures and continuing type of operation to make sure they are correct and up to date.

We are also trying to standardize these procedures so that they are the same at this site and the other site, and it is important that you have real firm discipline that people follow the procedure right down to the last period and the dot and exclamation point.

MAJOR GANDY:

I would like to add also that the Air Force and Aerospace consider approval for procedure change as important as approval for hardware change.

MR. ROSENBAUM:

We have configuration control on procedures as we do on the vehicles.

MR. LETSCH:

There were cases in the final factory checkout where anomaly showed up in the data, and it was felt this was probably due to the fact that an operator didn't exactly follow the procedure. This is something that you can never quite establish unless you have motion pictures or something of

the guy flipping the switches. It always leaves a little bit of doubt in your mind. Was it really this or could it have been something else that might later on get us in trouble?

MR. WEBSTER:

Webster, United Technology.

I would like to ask a question on this failure analysis bit, and that is, in your organization who has responsibility for initiating failure reports or detecting failures and informing whoever makes the analysis? What is your general arrangement in this line -- the diagnostic lab -- this sort of thing? Can you give a brief description of responsibility and flow? How does it get back from the failure -- the piece that actually failed -- back to the designer so that he is aware of it through the diagnostic lab analysis and so forth?

MR. CULBERTSON:

The whole activity of failure analysis rests with the functional department. They have a failure analysis lab, no matter which project office has the project, that comes back to it. They then initiate the failure analysis report and this is sent to the design group -- which has cognizance over that particular part -- for comment. It is a fairly straight line, because each piece that we have is under the direct responsibility of one or the other design groups, whether it is within the functional engineering department -- and they have some of the responsibilities -- or within a project engineering department. So this goes directly from the failure analysis group to that designer. It also goes to the project reliability groups and various other people.

MR. WEBSTER:

But these people can't be on the spot when the failure occurs.

MR. KREISLER:

Your question is who can initiate a request for a failure analysis?

MR. WEBSTER:

Yes.

MR. KREISLER:

Almost anybody, people on the site that detect the failure can initiate a request for failure analysis. There are certain items that must be failure-analyzed; design engineers can initiate failure investigations; almost anybody within the organization can do this.

MR. WEBSTER:

The designer is not a part of this team that makes the failure investigation to determine the mechanism of failure and the correction means; so are you not divorcing him from his responsibility?

MR. CULBERTSON:

You misinterpreted something I said. The failure analysis does not determine the corrective means. The failure analysis I referred to is a specialized activity of disassembly, if you will. It is an activity, the end product of which is normally this question: what specific thing failed, or what was the failure? They do not normally recommend corrective action, although they can. They don't implement the corrective action. This is up to the designer himself, and frequently the designer goes down to the failure analysis lab. I would say more often than not the designer will be represented during the failure analysis. The failure analysis in the way that I am talking about it is a pretty specialized activity -- to learn how to disassemble something so that you won't create something which hides the failure, so to speak. We do have specialists in this specific area. Does that answer?

MR. WEBSTER:

What is the means of preventing recurrence of that failure mode? Is there then a followup report made by the designer in response to the analysis that you spoke of?

MR. CULBERTSON:

Yes. He has to respond to this failure analysis.

MR. NEWMAN:

The failure analysis will be marked as a preliminary report until the final corrective action is documented on a failure analysis and when it is reissued as a final failure analysis report.

MR. ROSENBAUM:

It is completely documented. There is a complete followup procedure to ensure that the action is taken by someone. The followup responsibility is with the reliability people to see that the engineer designer doesn't slough him off and say, "You disassembled it wrong," or, "Some mechanic used it wrong," or something else.

MR. BALL:

I have a question. In Mr. Culbertson's remarks on poets, preachers, musicians, and reliability people, I would like to couple that with a NASA practice. NASA has been extremely insistent on the names and qualifications of people. It seems to me that your attitude to contracting is that you are very largely buying the services of people. I take it in your position you are often evaluating the reliability people that are being offered to you to go to work on your contracts. So I would like to ask your opinion on what you are looking for, particularly the comments on this. You are looking for physicists who can predict physical phenomena. In the electric micromodules at this time we have to look into the solid-state physics and predict modes of failure. We are looking, I think, for flight test engineers. They have been in the business of analyzing safety, effects of failure. We are looking for systems analysts, because you have to take failure probabilities and trade them out with other aspects of systems engineering. We are looking for industrial psychologists because a good deal of our program is in getting compliance with procedure. So now I revert to the question and say, in carrying out your job of evaluating the reliability staffs who are offered to you, are you looking for poets and philosophers or are you looking for something more specific?

MR. BAILEY:

This is purely a personal opinion now. When you talk about NASA, that is a big group of people, and they all have different opinions. My personal opinion is something along these lines: I kind of deplore this customer-seller talk that goes on around here because I think the kind of projects that we are engaged in, these exploratory things with a single vehicle and a single objective, I don't think we can make it that way. I think we have to be partners, and we are interested, of course, in the people who are going to be our partners, and we want them to be partners, and we want good, sound judgment, ability, and I think that is all.

MR. CULBERTSON:

In defense of what I said before, because I don't think you are misinterpreting what was said, but since this is being recorded, somebody might, so let me get this into the record too: this was not my definition of the reliability engineer. The point that I was trying to make is that reliability as a specific discipline is not well understood, I believe, by the average engineer or by the normal design engineer. The reliability engineer, therefore, has something of an uphill flight to make his disciplines known and understood, and I have just tried to get my reliability engineers to recognize that this is going to be an uphill fight, and it is a phrase that I have used to my reliability engineers rather than designers.

MR. FRANKLIN:

Franklin, of Hughes.

On this subject of customer and industry relations, we are entering an era now with both NASA and the Air Force of fixed-price incentive-fee-type contracts and cost-plus incentive-fee-type contracts, and these profit incentives are written around performance, schedule, and cost activities. The performance activities include such items as reliability and other measures of mission performance. The cost items relative to various operational phases in the schedule items are relative to many interim milestones. Some of these are very intangible, difficult to measure before the fact, particularly in your reliability and performance areas.

There is a tendency here to place a little more rigid requirement on the contractor to make tradeoffs early in the program, possibly at times when these are not desirable to the over-all program, in order to ensure the objective of motivating him to better management. I would like both customer and industry comments on the application of incentive-type contracts to space programs, particularly manned space programs, and to the results in terms of the over-all objective that these things can contribute.

MR. BAILEY:

My background is in operations. I have always been very close to the actual close operation of the vehicle. Incentive-type contracts frighten me with the fear that they might serve as inducements to a contractor's employee who commits an indiscretion of some sort, and not revealing it for fear that he will deprive his company of its incentive money and be punished for it. I don't think when you get down to the operating checkout area you can live with that kind of an environment. That is a personal opinion. I am not speaking for NASA as a whole.

VOICE:

There has been a lot of talk here about motivation all the way down to the individual level to get people to do a lot of soul searching and be very introspective of everything that can in fact be any part of the program's success. This is definitely a tendency for an incentive-type environment to move away from that.

MR. BAILEY:

To the extent that I can influence it, I shall always oppose any incentive contract that has any chance of inducing a fellow to forget to tell us that he dropped a wrench down in the capsule.

MAJOR GANDY:

There is a lot to be gained from the incentive-type contract. One of the things that we in government must be careful about with these contracts is that we don't get into the contractor's business to the extent that we force him, of course, to either give away his chance at making an

increased fee or that we give away government money, either one. With the cost-plus-fixed-fee type of contract, of course, we have been able to have a lot stronger control, I think, because essentially if we force the contractor to make a mistake we are going to pay him for it.

If you have ever been involved in an operation of trying to withhold a fee for something, it is a pretty tough job.

I don't envy the guys that have to sit and negotiate these incentive fees at all. That too is an extremely tough job. I think that the government program office people are going to have to be much more careful as to how they give their direction and the type of direction they give than we have been in the past.

MR. ROSENBAUM:

I would like to take a little bit of issue with John here about the incentive contract making people less interested or maybe more fearful of their jobs. To a contractor, an overrun on a CPFF contract gets as much attention both from his management and from the customer as some redundant fee on an incentive contract. I can show you some welts on my back as a result of that kind of activity.

I think that most of the people in the business understand what we are after, and the quality of work doesn't suffer or couldn't suffer because of an incentive contract.

I think that many contractors -- I speak for myself in saying this -- would welcome incentive contracts providing the incentives warranted or justified the risks that they are expected to take in connection with the incentive contract. Where the contractor is asked to take an incentive contract, he is also asked to take some risks in connection with it. If the two are compatible, I think you will find that contractors will take those contracts, will do a good job, and will make a respectable profit on them.

MR. NEWMAN:

The main thing that the customer is trying to do in writing an incentive contract is to give the contractor the same incentive that the customer

has. The customer wants lower costs, he also wants higher reliability, and in writing these contracts, if the customer and contractor get together, they can adjust the balance between reliability and cost so that they both place the same emphasis in the same area. If this is done properly, I think the incentive contracts will increase your reliability and cut costs -- not cut costs at the expense of reliability or vice versa.

MR. ROSENBAUM:

We have contracts in which a reliability number is an incentive factor in the profits that we will achieve.

MR. CULBERTSON:

We can go back to the RCS triangle. It was established, I believe, that normally this points one direction or the other, that for different types of programs, cost, schedule, or reliability can be the dominant factor, and it is possible to structure an incentive contract so that the incentives reflect this dominant desire on the part of the customer.

MR. KREISLER:

This puts the customer's desires in the form of dollars and cents. This is the emphasis we want on reliability; this is what we want on schedule; and this is what we want on cost.

MR. BAILEY:

I am afraid that we are going to have to break this off. We have run out of time. We certainly want to thank you all for your participation and evident showing of interest.

(Whereupon, at 3:30 o'clock p. m., the panel was concluded.)

Subject Manufacturing and Process Controls

Time 1:30 to 3:45 p.m.

Location Towne and Esquire Room

This panel will examine some of the Mercury-Atlas booster program manufacturing and process controls. These include: contamination, welding, and configuration controls; nondestructive testing, training, motivation, parts selection, test correlation, spares handling, transportation, production plans, and post surveillance and coordination. The panel also will examine the policy on rework, special procedures at composite, product completeness, and how to improve communications. Panel members are:

Col. M. K. Andressen, USAF, Chairman
Mr. E. D. Bryant, Astronautics, Coordinator
Mr. D. Archibald, Astronautics
Mr. G. Grossaint, Astronautics
Maj. I. B. Hanson, USAF
Mr. A. Hinck, USAF
Mr. J. Hopman, Astronautics
Mr. F. B. Kemper, Astronautics
Mr. S. Simkinson, NASA
Mr. L. Tuttle, Astronautics

MR. BRYANT:

Gentlemen, I guess people have disbursed to the various panels.

This is the panel this afternoon on Manufacturing and Process Controls. First off, I am Elwood Bryant, Vice-President of Operations at Astronautics, and I would like to make several announcements.

The modus operandi will be similar to those you had in this morning's panels, where panel members will give a few words on certain points that we would like to bring out, and following that will be a question and answer period.

I encourage you to participate in the session because I am sure that we do not have all the answers up here.

Starting over at your left, introducing the panel, I'd like to introduce Gus Grossaint, who is manager of Production Engineering at Astronautics.

Next to him is John Hopman, Astronautics factory manager for fabrication and assembly.

Following him is Frank Kemper, factory manager for electronics manufacturing; and

Larry Tuttle, who is now manager of operations for the Space Booster Systems Project. Prior to this recent appointment he was in charge of the assembly and test operations and subassembly operations on the Atlas boosters, and of course was involved in the Mercury program.

Then moving over to your right, introducing Scott Simkinson, who is the technical advisor to the director of the Gemini Project at Houston for NASA.

Next to him is Al Hinck, who is the chief of the Quality Branch in the AFPR Office at Astronautics.

Next to him is Major Mick Hanson, the Mercury Project officer of SSD R&D; and

On my le . here is Dave Archibald, who is the chief of Reliability Control for the Atlas Weapons System. Prior to this assignment, Dave was in charge of all quality control for the Division during the period prior to projectization and had a great deal to do with Mercury.

I would now like to introduce your chairman for the afternoon, Colonel Malcolm Andresen, who is the AFPR at GD/A.

COLONEL ANDRESEN:

Thank you.

Gentlemen, to start off the afternoon session, that portion on Manufacturing and Process Controls, I would like to call upon the various panel members who, in their particular specialties, had much to do with the techniques, practices and disciplines of the Mercury Program.

I would first like to call upon Mr. Grossaint.

MR. GROSSAINT:

The manufacturing plan for the Mercury Program was established in the same fashion as had been established on previous Atlas missiles, as well as those missiles under current production at Astronautics. It was actually a byproduct of some of these other plans, tailored to fit the Mercury Program.

One of the major differences is in the area of the flow time extensions in major component manufacturing, final assembly, checkout, and composite.

In final assembly, checkout, and composite, the flow time extensions were approximately 75 percent with the man-hour expenditures increasing from 60 to 75 percent over other programs, such as the E and F series weapons system.

The increase in flow time and expended hours was brought about by administration of greater care in fabrication and assembly of the hardware and the establishment of closer tolerances in parameters in our test procedures.

Of the many precautions taken on Mercury, one specifically was the identification of the item and configuration control paper. This was accomplished by a large Mercury overstamp. This tended to add emphasis to the identification of the task to motivate personnel to be more meticulous in their work.

Another item to refine controls was the establishment of a centralized welding technology center, wherein we pulled together all of the responsibilities pertaining to welding that were throughout the division into one centralized group whose authority it was to prepare all the engineering, welding specifications, proof engineering designs as pertained to welding, develop all of the welding schedules, the training of the welding personnel, and the certification of these people.

It was also their responsibility to add to the welding machinery and equipment, improved controls and monitoring equipment.

During the Mercury Program we also decided to improve the controls and reliability of our welding wheels and types, more rigid inspection requirements were established, and the control and issuance of these wheels were put into the tool service department and they were kept under lock and key.

Another item to control the welding and tolerances was the decision by tool engineering, quality control, and the factory to review the major welding, the critical welding tools and equipment, establish maximum out-of-tolerance, and then prior to the start of any major component into these tools, the requirement was such that they go through a major inspection to verify that the tool was in these acceptable tolerances.

Another activity that was exerted on the program was that of material handling. The material handling specifications that were currently being used in the other Atlas booster programs were reviewed and updated to provide more stringent controls in the handling and packaging of booster parts coming in from vendors, as well as those parts made within our own plant.

The critical items that we felt should require this extra tender loving care were reviewed to insure that adequate packaging and handling devices and/or tools were made available to insure their protection during all phases of receiving, warehousing, manufacturing, and storage.

The additional welding controls that were established and the material handling could not alone be attributed to increased reliability on the Mercury Program, but the results have played an important part in our achieving this reliability.

MR. HOPMAN:

When we became aware that the Atlas would be used as a booster for manned flight, like everyone else we did a lot of soul searching.

We quickly became aware of the possibility of using the Mercury Program as a medium of motivating our workers. Unfortunately, in fabrication and assembly operations it is difficult for a worker to associate his work with a completed product.

However, we found now that we could have the worker associated with the completed product. We did this by the media of posters placed throughout the factory areas, articles in our company paper, and, probably most important, we conducted group sessions with the workmen, emphasizing the Mercury Program.

We pointed out that any detail or assembly that he might be working on might be used on a Mercury missile. Furthermore, those components considered critical to flight systems received that extra tender loving care as they progressed through the manufacturing operations.

Contamination control was another area to which at this time we had to face-up. Previously we had been able to compromise to a great extent on what was considered safe.

The Mercury Program changed this so that we no longer could compromise. First, complete and definitive parameters were determined as to the amount of allowable contamination. Previous specifications were broad as to inspection requirements and these had to be pinned down and clearly defined. This resulted in new facilities, procedures, and techniques. Special training sessions were held for all personnel involved in cleaning to assure that they not only were thoroughly familiar with the cleaning operations, but also aware of the importance of doing a good, conscientious job.

Frank?

MR. KEMPER:

In the electronics manufacturing we were faced with a rather distinct challenge when the Mercury Program came along because we didn't have two standards of manufacturing or two standards of quality in the missiles and space business. You only have one standard and that is the best you can do.

So this caused us to step back and take a look and see what we really had here and how could we really work on this program to assure ourselves of some more reliability.

Well, we came up with several ground rules that I feel are rather important; in the first place, we established a policy that we would allow no rework of failed components, and if a component failed, that obviated its use on the Mercury Program. This caused, of course, some soul searching and thinking, because it was recognized that these boosters would all be different. We couldn't build them at the last minute, so we knew we were going to be faced with modifications, and this is distinctly different from a rework for a repair.

So we set up a geographical location somewhat removed from our production area and staffed it with our top-grade, our best technicians and our better and best quality control personnel. Also we caused to be placed in this area engineering personnel that could work with the other groups and really go through these modifications and see if they were better to modify, or would it be better to start all over, and this is a program which paid us off quite a bit.

This led us to the next major factor. It had all along been our program to ground-test everything very thoroughly, and we took the data and recorded it and filed it. We thought, "Well, we can make some money here. We will take this data and we will duplicate it and we will attach it right to the canister of the part and send it out in the field attached right to it and it will become part of the history." We still had our files.

This caused us to do some other thinking about test equipment, because when we started off there was a difference between the test

equipment in the two places, the field and the factory. We right away realized we'd have to work on this, so we started toward the duplication of our test equipment so that the data we sent down could be really very closely correlated and we would have something to basically work upon that was a good solid tool.

To enhance this further, we took our techniques and our quality control representatives and transferred them back and forth intermittently between the bases and the factory where they participated in the tests at both ends, and we encouraged them to phone back and forth and say, "Joe, how did you get this?" and any little anomalies that would come up they would be free to discuss them.

About the only other major thing we ran into, and we used a lot of women in our industry, was the morale factor, and you have heard about these things.

When you have women working for you, there is nothing in the world like a public figure, one of the astronauts walking down the line, telling Ruth and Mary, how they appreciated what was done and exhorting them to do better. This really paid off later.

MR. TUTTLE:

I will speak for the final assembly and checkout activity. We man the Mercury docks with selected technicians, inspectors, factory engineers, and supervisors and reduced turnover as much as possible.

We stressed: "This is your project; these are your docks. You are the Mercury checkout team."

We stressed the team activity, as you heard mentioned in this morning's initial talks. We gave them classroom training and also stressed the national importance of the Mercury Program. We gave each of them special Mercury badges and shop coats and restricted work on the Mercury birds to those employees who had been issued these special badges.

Brochures, pictures of the astronauts and of Mercury flights, and other literature concerning the Mercury program were passed out to them from time to time.

Identifying signs were placed on each of the birds and also on the stands that held the birds manufacturing and inspection papers.

The plaque on my right (indicating) was on one of those stands and kept constantly in the minds of the team that these birds would carry a passenger. The photographs also show the other signs that we had in the area.

In all, this developed a strong awareness of Mercury and a very definite team spirit.

Our factory testing consisted of an independent test of each booster system, and then after these were completed, a composite test of all systems running together.

A Mercury bird had to be in flight configuration before these tests were acceptable.

Normally, GD/AFQC cleared a booster for composite testing, but in the case of Mercury AFQC, SSD and NASA also reviewed the booster configuration and the systems test data before a bird could go on to composite testing.

These men also checked the composite test data before a bird could be removed from the checkout dock. A more stringent criteria was used on Mercury for clearing any glitches that showed up in the systems and composite test. Each glitch had to be completely accounted for and removed, even though it could be isolated to test equipment or be proved to have no effect on flight.

We also learned to be more deliberate. Before any electric package could be removed because of failure or suspected failure, failure analysis personnel double-checked the findings of the factory.

After removal, the component received a complete failure analysis. Subsequent testing of that system could not be resumed until a failure analysis report was issued that isolated the trouble to the removed component. To tie the complete history of each bird together and to have it available at the launch site, a quality control engineer was assigned full time to the Mercury Program and he followed each bird through final assembly, checkout, and on to AMR.

Furthermore, a missile engineer reporting to the assistant program director also followed each bird through the factory and remained with it at AMR until launch.

Dave?

MR. ARCHIBALD:

I would just like to add, perhaps, a few comments concerning some additional disciplines that were applied to the program.

One, we had a special materials review team and as far as the quality control member to this particular board was concerned, he had to be a supervisor and assigned and of course selected by the Primary Materials Review Board.

Also, our Mercury Program was an R&D effort, but systems were not accepted without full engineering release.

Now, as an illustration to you on this subject, we had hundreds of changes really between our first Mercury system, which was 10-D and 130-D, with long storage periods in between to compensate for the schedule demands.

Also, as far as critical components were concerned, if we did have a problem between the factory and the launch site, these critical components were actually hand-carried by air or whatever the transportation media was.

In addition to the items mentioned by Larry concerning our final acceptance test activity, which the configuration, as designed by engineering and as programed by the manufacturing plan, was also varied before we got into our testing.

Now wherever possible our post-engineering changes were programed at the factory and along with the installation information instructions were delivered as a package to AMR or the launch site.

Now a couple of these programs that we have had in effect, that we also feel helped us a great deal, was our search for critical weakness

program. Now this was mentioned earlier, but it does complement the over-all acceptance testing for each component. Our search for critical weakness testing, of course, was destructive in nature in most instances and carried the item really beyond the design limits, and of course this was to really verify this safety margin that we had and also check more accurately the life limits involved.

Our other sampling plan consisted of a production evaluation test which was to select certain components on a sampling basis and subject them to what we felt were the most critical operating environments and this was, of course, stretched to the design limits. We omitted such things as shelf life and things of this nature as far as our environment was concerned for this sampling criteria.

The other thing was our critical component selection criteria. Since you can't shout "wolf" on everything, this criteria was designed primarily for the man-in-space mission. In this critical component selection, no history of repair or refurbishment was permitted. The watchword was "do over" when an error was made.

Now is it perfectly obvious when we had designed a tank and started in production that we couldn't scrap that tank entirely for one spot-weld error, but in this regard we did bring to bear the best talent that we had and the decision had to be made by this special materials review team that I mentioned earlier.

Now, operation due to test time, if this was excessive or above average, was also a cause for decision against that particular component for use in the Mercury Program, and also this was mentioned a little bit earlier, but I think to provide a little bit of clarification for it, when a group of parts or components basically were tested, we did select those items which had the best operating performance or the optimum, either the high or the low tolerance exercised.

Now these decision-limiting criteria were exercised prior to the application of this identification decal that we have also discussed, but this little identity decal, of course, had as its mission to convey to the next operation or the next station in our manufacturing sequence that this was destined for the Mercury Program.

Major Hanson?

MAJOR HANSON:

Maybe I can carry the discussion a little bit further into the acceptance of the vehicle itself here at San Diego.

The pilot safety program which was described earlier this morning allowed us to concentrate our effort toward control points. One of these control points is the acceptance, final acceptance of the vehicle here. We have a formal acceptance meeting established where we have focused all of our efforts toward the last few weeks when it goes into composite test and we are preparing to accept the bird, and at this formal acceptance meeting we go very deeply into the history of the vehicle.

We are looking at the configuration of the vehicle very carefully, the review failure analysis. This was discussed earlier this morning; we are sure there are no incomplete failure analyses. We are very positive there are no shortages on the bird and we go very deeply into it, even to the extent that we insist on certain special studies or tests to be completed at this time as an acceptance criteria.

Another area which we possibly could discuss very briefly is some special testing we do. With the major weapons system program it is hard at times to find a small problem and to go ahead and retrofit the whole fleet. With us we are a little bit more flexible so we can go ahead and establish some kind of special testing if we see a minor problem that we don't want to make a change. The change could possibly hurt us; we would rather go ahead and test for it so we will set up these small minor tests, and we have very many of these tests going in the program and I think they have helped an awful lot to give us more assurance that the vehicle is a reliable vehicle.

Al?

MR. HINCK:

Although we get a lot of assistance from other groups and personnel, the responsibility for the final acceptance of the Mercury booster is that of the Air Force quality control, and therefore all the topics up here on this

little tickler chart (indicating) are a consideration during the normal acceptance task.

In the missile business it's pretty well established, you've only got one chance for a success. This is further emphasized by the Project Mercury Program and the fact that we at AFQC have the over-all acceptance responsibility of many mandatory inspections.

And control points were established to assure the acceptance of quality and reliable hardware. Examples of these controls are in the parts selection, electronic component test verification and physical inspection, witness and evaluation of composite and system data.

Physical zone inspection, which for a matter of interest is accomplished eight times for each zone on a Mercury booster, starting initially with the shop and including by the final review by Air Force quality control supervision after the roll-out technical team has accomplished their walk-around inspection.

Configuration control, the review of all missile records, critical component documentation, failure analysis reports, both the preliminary and final reports - these are only a few of the many items wherein we have established control points, all of which are systematically controlled through the use of status sheets and check list.

In addition to these points which have previously been covered, there are other special status evaluations performed to determine the physical condition of the booster and also to detect early in the program any problems that might impact the total program.

The precomposite meeting is one; the composite technical acceptance meeting, which is conducted after the data has been reviewed and is in the file, meaning no concurrency in the data review.

The final, as was covered, was the factor of roll-out inspection and meeting, wherein the physical, functional and general status of the booster is again totally reviewed to determine readiness for acceptance.

On Project Mercury we have implemented a system wherein we provide as close coordination with the sites as possible, acceptance

surveillance. This entailed the shipment of or the accompaniment of an Air Force representative with the missile. He personally would coordinate the shipping and receiving problems at the site.

We further maintain complete coordination with the site personnel up to the point of launch so that we had all feed-back data; we could provide sufficient support to the problems that they had and also to preclude reoccurrence on downstream birds.

We also would look at the other test programs and determine whether they would impact the Mercury boosters, and this information was also coordinated.

The foregoing is only a limited example of the many steps taken to assure acceptance of a Mercury booster which was suitable for a manned flight.

Scotty?

MR. SIMKINSON:

You have just heard from many of the people who were directly involved in the daily manufacturing and tests of the Mercury-Atlas boosters, and their brief description of the various areas of endeavor comprise a thumbnail sketch of the planned methods, factory operation, and represent the best current courses of action known to all parties.

Now obviously I read that sentence and I would like to go back and pick up three key adjectives I used there.

The first one is "planned methods of operation." It is inevitable on a program such as this with the continuous failure analysis and corrective action going on and the continuous effort to produce a better missile all the time, it is inevitable that you will run into cases where these planned methods suddenly come to a halt because you can't do it any longer, and I think on the Mercury Program we tried desperately and succeeded, I am sure, in getting the proper level of management in each case, whether it be at the inspection level, the design level, at the Walter Williams, Jim Dempsey, General Ritland level, it came out with the right answer because it was in the right perspective and we proceeded without damaging the schedule any more than we had to.

I think this is a real pertinent point and we can't ignore it. Schedule is still in front of us, but quality quite often produces a better schedule and it takes a pretty good brain to decide when you apply which.

Now the second two adjectives that I used were the "current courses of action known to all parties." And here I would like to say that many of these methods and controls that you have just heard about were not in existence or were not being enforced in the early days of the Mercury Program. They were actually brought into being by the needs of the program as we went along.

In order to understand how this evolved, I think it is interesting to note that there initially was no clear definition of specific requirements imposed on the Mercury boosters by the Air Force or by NASA except that each individual booster should be the best that the normal design and test allow.

In addition to this, there was, of course, and you have heard this today, the automatic abort system to take care of the problems that had to be tolerated with this approach. Now after the program reached the hardware stage and Mercury flight -- and I hate to use the word "failures" -- being a reality, along with the attendant serious over-all delays, it became obvious that a different approach was in order.

One necessary step I think taken in the right direction, was to improve the information flow, the communication lines across all organizations. This again was touched on quite extensively this morning. It is nevertheless important, and I feel worth repeating.

This capability didn't come up overnight. It didn't come up over a period of months. It took years, and it developed over the duration of the program. You recognize the problem areas and bring it in the proper form before the necessary level of management, and usually a management team of the contractor, Air Force, Aerospace, and NASA. This method of operation I think is a firm requirement for an effort of this magnitude and will continue to be so, and those of us who are now connected with Gemini I hope have carried this lesson into that program. I think it is in order to say here that practically all the information gained during the Mercury Program is being or will be applied in the Gemini Program.

It doesn't apply just to the Gemini launch vehicle. It applies to the space craft itself and to the Agena and Atlas booster for the Agena in the rendezvous missions.

When we get into the discussion period a little bit later there are some areas which I think we ought to all think about asking questions on. They were touched lightly up here, critical components, their choice and what to do with this list after you have it. The rework policies for defective parts, where a failure analysis or just an analysis of the system showed that a change should be made late in the game and you don't have any parts available. Just how you handle this was touched on lightly here.

I touched a little bit on the revolving triangle that Mr. Dempsey used this morning, the reliability, cost and schedule, and this was discussed a little bit in the morning session in this room on Human Factors, and I think it should be a continued discussion here of how you get quality in at the right amount to enhance your schedule, rather than ruin it.

And last, but not least, my favorite subject, configuration control.

COLONEL ANDRESEN:

Gentlemen, you have heard the members of the panel.

I want to remind everyone that this is a workshop and it is for the express purpose to exchange ideas, and questions are certainly welcomed from the floor, and while many of the things that we discussed are common to your particular organizations in its problems or practices I would like to invite your comments or criticism or additions to what has already been said.

Are there any questions at this time?

MR. WARING:

Waring, NASA Headquarters.

Usually with more stringent controls being placed on activites within the plant and so forth, it usually follows that you also increase your work load as far as paper is concerned.

Would you or any of the members of the panel like to comment on any method or technique you might have used in order to facilitate communications and at the same time not get bogged down with paper work?

COLONEL ANDRESEN:

That is a very excellent question and it is one that confronts all industry as we go into more complex design and more difficult articles, and I would like to ask if there are any members of the panel who would like at this time to start the discussion on this particular point?

Mr. Archibald?

MR. ARCHIBALD:

I can certainly agree that paper work is a burdensome thing in our manufacturing activities today. As far as the Mercury Program was concerned, we used primarily what I guess we would classify as public media to communicate the importance of this program, the posters, the overstamps on the manufacturing paper which indicated Project Mercury; by identification of the individual project units with large signs such as we have on our poster up here (indicating), so that it would keep the fact that they were working on a manned vehicle constantly before the employees.

Where we did get into an individual, and I think a paper work load that hadn't been experienced on our ballistics missiles, was on this matter of final documentation. We did get ourselves involved in a considerable amount of extra information that was compiled for the consideration of the acceptance team.

Along with the compilation of a tremendous amount of data on the history of the manufacturing for the missile itself, individual subsystems, now these were selected; not all of them had a historical record, a narrative record that was put together concerning its history.

In other words, how many times was it submitted to acceptance tests; what were the problems found; what was done about those problems, that is the documentation that Frank Kemper earlier discussed that went along with again the prime subsystems.

But as far as any additional paper work, except the contract changes that were involved, and directives, there were very little save this final acceptance information, with the exception again of the public media that we have discussed previously.

MR. HINCK:

Another comment that might be incorporated here is in the area of critical components wherein at the time of receipt the paper work was identified when the component was marked with the Mercury decal, and this was maintained in special control so that at the time of acceptance these papers were readily available for review and the prime purpose of this availability of these records, performance data, was to allow the evaluation of the original components' performance against that as a part of the integrated system to determine if there was any degradation during the manufacturing utilization.

MR. BRYANT:

I would like to make just one other comment, in general.

While on Mercury, as these boys have described, there was not too much increase proportionately on paper work as such; however, there was a considerable increase in the amount of man-hours, whether it be indirect or direct; whether it be technical or mechanical, in the shops and in the offices; in looking at this paper work that they have in the shop and making sure that everything was as it should be.

In other words, extra effort throughout the whole system to police it, to assure ourselves that we were following the rules.

So there actually was an increase in cost there, rather than in the paper work per se.

MAJOR HANSON:

Could I make one comment, Colonel?

Actually, we did shoot for key documentation, again at the end for acceptance; this was used for communication configuration comparison charts, things like that.

COLONEL ANDRESEN:

Do we have a comment from the floor?

FROM THE AUDIENCE:

In conjunction with the discussion here now, would it be in order to ask what sort of a documentation is involved?

In conjunction with that, what sort of documentation followed with this quality control and Air Force individual who you spoke of as a vehicle moved from the plant to the launch pad?

COLONEL ANDRESEN:

Would you like to discuss, as I understand the question, the documentation that accompanies the missile as it goes from the factory to the Cape?

FROM THE AUDIENCE:

I am concerned with the level of detail.

COLONEL ANDRESEN:

All right.

Mr. Hinck, would you care to treat with that one?

MR. HINCK:

The documentation is actually broken into two packages.

From the factory and accompanying the missile is an acceptance package. It's in volume something like about four inches thick. It contains things such as component history records; the entire configuration documentation; rubber cure date; different types of logs; all of the open planning, if there was some, and we might point out here that we did achieve the zero open planning and completed tasks on the last couple of birds.

Summary of the factory test data; the other portion of this data which was forwarded, is some that was produced out of Aerospace. It is a document of quite a detailed magnitude which goes in and summarizes the entire history of the buildup of this bird in the factory.

That is -- I mean I'd have to have the documentation to show you and I would be more than happy to.

That's all I can dig out right now.

COLONEL ANDRESEN:

To add a little bit to what Mr. Hinck has already told you, I would like to point out that the amount of documentation that now accompanies the missile is so extensive that we are currently sending one of Mr. Hinck's men along with the missile and the documentation to help interpret it when we get it at the other end of the line, in case there are any questions which arise surrounding the documentation. If they can't be ascertained from the documentation itself, we then have a means for feeding back into the factory and obtaining any clarification that may be required.

There is also one other point that might be interesting to touch upon on this general question of documentation. It is a point that we learned early in the missile program, and I would like to just take a minute to throw it out on the floor. Back in the period '58, '59, and '60 in the missile business we started to recognize that as we went from the test phase into the operational phase more attention must be afforded to configuration control.

This was highlighted several times during the earlier phases of the missile programs when we tried to go back and examine test data and to examine why we were having difficulties with different missiles that we had launched. When we tried to determine the exact configuration of some of the missiles that had been launched, we found there was no system of reliable documentation that told exactly what those missiles looked like that may have made them fly differently than other missiles.

So at that point in time we started a very extensive program of configuration control which was carried through and perhaps found its highest degree of perfection in the Mercury Program. That was a little additional

bit of knowledge that we gained from the initial phases of the missile programs, and I think it is illustrative of the type of development in our method of control and our procedures that have developed throughout the course of the growth of the missile program.

MR. BUCKLEY:

Buckley, Douglas Aircraft.

Obviously the need for all these extra efforts wasn't apparent at the beginning of this program and much of them were not recognized until after some of the early failures.

I am wondering what problem you had in getting funding for these extra efforts, or did you have a blank check on this program?

COLONEL ANDRESEN:

Of course there was not a blank check.

There was this: there was, as was mentioned earlier today, a recognition that there was a tradeoff between what the objective we wanted to achieve was and what we could afford to pay to obtain it, and we felt that this type of documentation would pay big dividends and therefore we were willing to accept the additional burden, costwise, that it may impose, and I would say this, if we had it to do over again, among the things that we did, I think this is one of the things that we would spend the money for again.

MR. BRYANT:

I might comment a little bit on that from a management side of the picture, and that is, in truth, we never did catch up. As we found out we needed certain things, we did them, and we hoped that we would catch up with cost coverage at a later date.

As a few of the things happened, we tried to assure ourselves that we kept track of these and it was through the routine, that we call the ECP's or engineering change procedure.

An ECP would be estimated and of course, as we developed in the program, the ECP would reflect the experience that we had accumulated to date as far as cost is concerned, and it was interesting to note that as the program progressed we could see the number of hours for instance required to produce a Mercury bird going from a figure to about double the figure which we were using on the weapons system missiles.

I think our cost figures then in our estimates would reflect this added experience, but it also lagged behind, if that answers your question.

Of course, they were CPFF contracts, and as Andy has indicated, there was a very definite recognition on the part of the customer that this was occurring and was recognized as we went along also, so that eventually it worked right along together, and we did not have too much difficulty in this area.

COLONEL ANDRESEN:

Sir?

MR. WALTERS:

Bud Walters, Airite Products.

I notice along the field of documentation as the space and other missile requirements of documentation increase there is a problem throughout the industry of documentation requirements in a specified form are becoming more and more vague and scattered, wherein much wasted effort is involved in trying to determine documentation requirements by component suppliers to get the proper documentation to the end item.

There is a lot of feedback, loss traceability due to requirements not known until it was too late to incorporate it into the program.

I thought it would be a comment to bring up at this time for elaboration for improvement throughout the area.

COLONEL ANDRESEN:

I certainly think that is a very valid observation, and I am sure that more standardization would be helpful among the aerospace industries to lessen the burden in this area.

Is there anyone that treats with that problem specifically that would care to comment?

MR. HINCK:

I think that possibly this feeds back into what I said a few moments ago. As we progressed down the knowledge trail, we found out that by capturing this documentation when the part was received or was in the receiving status, when the paper work, performance data was attached to the part, we eliminated a major portion of these wrassling matches to get documentation for something that had gotten installed and we found we were short on the paper.

MR. WALTERS:

The main point that I had in that matter was the fact that the initial designation of required documentation is too vague or scattered in that the supplier of the component or part is never completely sure of what documentation is required at what time or was required to be sent or retained for traceability.

MR. BRYANT:

I think probably that is one of the lessons we have learned that we have yet not been anywhere able to come anywhere near to perfection.

I know just recently here we had a large meeting out at the plant on this very subject, that the suppliers were not getting the communication properly; the specifications which we issue are listed, but the exact type of documentation which we require for verification is not always the best.

Frank Traversi, I see you down there.

Would you like to comment on this and the experience you've had?

MR. TRAVERSI:

I think not. I think you have stated it fairly well. It is something which we are trying to improve all the time, but we have not yet achieved perfection because of the many departments which have to interface with this particular problem.

Take an organization the size of ours and you can't always put something like this in the pipeline and have it come out perfect at the other end.

MR. SIMKINSON:

I might add something here.

COLONEL ANDRESEN:

Yes, Scott?

MR. SIMKINSON:

In the Gemini Program with McDonnell, our prime contractor for the space craft, early in the Gemini Program as a result of Mercury experience, we generated a document which called out the documents. This is a contractual document and it lists precisely to the supplier what he has to supply with his product. He knows this when he bids on the contract and this is negotiated at the bargaining table, and unfortunately we ran out of some funds, we didn't get all we wanted; at least he knows what he has to do with this document.

MR. WILLSEY:

I am Bruce Willsey with Solar. That is a help and we recognize it, but when you want one type of documentation and Douglas wants another and Lockheed wants another and Boeing another and North American another, and you try to amalgamate these in a major sub's plant, you have a real problem of coordinating all these documents. I find it difficult to believe that paper work has gone up moderately.

It hasn't in your plant. It's gone up significantly.

MR. SIMKINSON:

Yes, it has, but I hate to use the word I heard a little earlier, "bogged down with paper work."

I don't think this is true. I think we can look at the record of some programs where we have required considerable documentation; we have come out ahead over-all on the program. I know it is a problem of an immediate nature when the contractor is suddenly faced with expense he hadn't counted on, and as Elwood stated, this is a problem that needs some work.

MAJOR HANSON:

I would like to make just a short point.

Actually, personal contact can reduce this paper work an awful lot. Look at the relationship of the Air Force to GD/A, it is the same as possibly GD/A to the supplier. We have quite a bit of documentation but it is assembled from existing documentation. We don't have a lot of requirements; lots of personal contact between Aerospace, Air Force, and GD/A. This can reduce the paper work an awful lot.

MAJOR JEANCON:

Can I elaborate?

Major Jeancon from SSD.

I think what you gentlemen are bringing out is a sad lack of up-do-date MIL spec. requirements all the way across the industry.

We are in most instances about 20 years behind on exactly this type of thing, and although this is not the time to point out problems, but you in Mercury are doing and did require different reports, different types of documentation than we required in the weapons system, and this is exactly what this gentlemen is bringing out.

If in fact we had standardized requirements brought up to the level of the modern technology instead of back in the B-24 days, which most of

those are currently in that era, you wouldn't solve the problem but you'd be an awful lot better off. I think you will note from the USAF and ASFC position, there is a great deal of effort going on in this type of work. Unfortunately technology is running faster than the paper standardization type program is coming out.

COLONEL ANDRESEN:

Mr. Traversi, did you have a comment?

MR. TRAVERSI:

That is the comment I was going to make.

Here we have a situation which is very dynamic. If we could cut it off at any given point, then we would not run into the problem we have in this area.

Problems are brought about because of the constant advancement in technology and the constant changes we keep pumping into any program of this nature, and I think the Major has already expressed that.

COLONEL ANDRESEN:

All right.

I have another question in the rear.

COLONEL FEARING:

Fearing, Seymour, USAF, Colonel.

Do you think it is in order to make any comment at all upon General Shriever's data work and management group in this connection?

COLONEL ANDRESEN:

I think it would be fine.

Would you care to comment on it briefly?

COLONEL FEARING:

Well, briefly, General Shriever has, under Colonel Stevens' staff, a task force which has been operating something like six months now, taking a long look at the flow of all data as we do to all systems, particularly as it reflects itself against the management process.

And this is quite a big group and the schematic here is to standardize on data generally, and of course, coming out of this would be revised specifications, such as the Major mentioned in the form of MIL specs.

It applies specifically to such as has been covered here. This is a terrific undertaking; I believe, Colonel, the deadline on this project is something like September of this year, and out of this -- it certainly isn't a cancer cure, but it ought to go a long ways toward covering things generally as Frank mentioned here, short of the evolutionary processes that goes with technological development, this is being developed by the Air Force right now.

COLONEL ANDRESEN:

Thank you.

Are there any other comments?

FROM THE AUDIENCE:

I might take it away from documentation a minute, if I won't make anybody mad.

If I heard you people, individually and collectively, I thought I heard you say you were building a common product and you had at least two levels of procedural approach, two levels of documentary documentation approach, and two levels of acceptance. If this is true, didn't you create a potential, at least while you were upgrading the vehicle for Mercury, downgrading the vehicle for its other applications; if so, how did you cope with this, and if so, what was your customer's reaction for the other vehicles?

COLONEL ANDRESEN:

Well, I think that perhaps I had better treat with that one myself, because I have been on both ends of the line.

At that time I was not engaged in the Mercury program but was engaged in the operational program. The things that we are talking about as being beneficial to the Mercury program also had a beneficial effect on the weapons system program, and there was a mutual exchange of information back and forth.

For example, we had a change control board on the Atlas weapons system and we also had a change control board on the Mercury Program, and each change that was proposed was exchanged between the two boards and were considered as to applicability as to the operational system and to the Mercury Program, and so in effect I don't feel there was any degradation of the operational fleet that the Air Force introduced into the inventory as a result of those differences that may occur between the Mercury missiles and the weapons system missiles.

MR. BRYANT:

I would like to comment on that just a little.

Andy is being very kind. I think that what he said was completely true as a fundamental that we learned and a practice that was actually carried out.

However, to this day we have this question being raised and throughout the Mercury Program. Maybe some of these boys are going to say, "Why do you say that in a public meeting?" but I think it is important that this real basic question be discussed freely, and that is that when you have a program like Mercury and other programs going on you are bound to have a reaction of, "Well, if it's good enough for them, why isn't it good enough for me?"

Now the fact of the matter is, gentlemen, that it is good enough for the other program too, and we must remember that we are still learning and the Mercury Program was the first time in this country and in the aerospace business that we had such a challenge thrown at us, a motivation,

so to speak, to really take a look at ourselves and see if really we were coming up to snuff. I think this morning in the keynote address Walt Williams brought it out particularly that one of the main things learned in the Mercury Program was the ability to weld ourselves together as teams and I think one of the things that we've learned on this question is that we must do better, the missile business, the booster business, very much related to each other, is going to demand that we have a similar type of awareness of the reliability that we must build into the product must be in all of the product if we are going to continue to develop and I didn't want the question to go unanswered that we did not recognize that there was a very great pressure on us during the Mercury Program. There still is and it isn't completely solved.

Just one final comment, quickly, if I may. It is possible, as we all know, in industry and at the customer level also that you can put an effort like we put on in Mercury and you can put it on at one time. If you want to put that on everything as an effort, extra effort, you are not going to come up with the same result.

Therefore, what we are learning on Mercury and have learned on Mercury, some of it is going to wear off on the other programs, and we go on to the next one so the next effort may be even at a higher level on one program and it keeps bouncing back and forth.

I think I am fundamental in this; maybe someone has an argument.

COLONEL ANDRESEN:

Is there a comment from the back?

MR. MacNAMARA:

Joe MacNamara from Rocketdyne.

We used to supply all of the engines for both the weapons system and Mercury Program. I just wanted to make one point, that there is absolutely no differentiation between these two programs at Rocketdyne.

The inspection procedures, the quality is all the same, and today there is still interchangeability between the Mercury engines and the

weapons systems as far as the parts are concerned, so we did maintain single level of effort on these two programs.

COLONEL ANDRESEN:

Thank you.

Comment?

FROM THE AUDIENCE:

The discussion is now getting around to something that has interested me for a long time, and that is I have always been told that the cost of maintenance of the military product might run anywhere from 10 to a 100 times the original cost of that same product to the military and I have always asked the question, "Well, why can't we spend more money on basic reliability at an increased cost, initial cost, and then reduce the cost at a later time?" and I always get the same answer, "Well, it is coming out of two different pockets," and I was wondering whether the military is using a system approach or will be using a systems approach to try and decide where the tradeoff is on initial cost versus maintenance cost in the future.

COLONEL ANDRESEN:

Well, the cost of the initial cost versus the maintainability cost is, of course, always a compromise.

It is normally the objective of the people who have charge of a weapons system program to inherently design into it all the features that will add to it and enhance maintainability that they can at the time of the original design, and we do recognize maintainability and it is reflected in our reliability objectives.

However, when we get out in the field and as time goes on, we learn new things in the state of the art, and it is more often the sort of things that would enhance maintainability, rather than a determined compromise that we made initially in sacrificing reliability for dollars.

I don't think it's really a compromise that is often made.

MR. TUTTLE:

I would like to come back, if I might, Colonel, to the question just a minute ago and express the thoughts that we had at the checkout level.

While there is every indication that we tended to have two standards, in reality tremendous effort was made to inform our people that all our birds were of the same top quality and just as rapidly as improvements were made through Mercury, many of these became incorporated, sometimes surprisingly quickly, on the other birds on the line, and often we have said to ourselves when something is found to improve or on some technical advancement on Mercury, we sort of brace ourselves because we know it will be very shortly that this will be required on the other birds too.

So we were keenly aware of this on the line and were working to bring the temperament of the people and the quality of the product right along behind that which was established on Mercury.

FROM THE AUDIENCE:

May I amplify that just a little bit?

Since my job was definitely configuration management for the Atlas weapons system, one of the major fallouts we received out of the Mercury Program, surprisingly enough, was what it did for the Atlas weapons system. The major area of benefit we received was the fact that the engineering on Mercury had a different bias than the engineering on the weapons system.

You had a different group of people looking at it from a slightly different approach, and you cannot take two groups of engineers to come up with the same problem and answer it in precisely the same manner.

This difference of opinion, this difference of approach, this change of engineering bias, if you will, was a tremendous aid to us. We would find ourselves going in one direction on the Atlas and Mercury would come up with a surprisingly simple, straightforward solution, maybe the other way around, it is immaterial for this discussion.

Immediately people would recognize, "Hey, wait a minute, here is a most excellent solution. Let's use it."

As a direct result from a CCB standpoint, probably within the weapons system board, the most commonly used question was, "What is Mercury doing about this problem? What was Mercury's solution?" and, if for no other reason, this forced our weapons system engineers to do a lot more digging, a lot more information and, frankly, come up and tell me why they couldn't use the Mercury system or vice versa. It was a tremendous fallout upon us, just exactly this one simplified point, that of the engineering bias.

FROM THE AUDIENCE:

Dave, I haven't put you on the spot for a long time.

How did you do this material review, reject it on Mercury; did you throw it away or put it on the Atlas?

MR. ARCHIBALD:

Sometimes we put it --

COLONEL ANDRESEN:

Mr. Hinck.

MR. HINCK:

As far as the material review portion, well, let's go back and restate the policy.

No rework, reworked parts would be put on Mercury. We had a special controlling board for this, materials review board.

The exception, rather than the rule, was on these failed parts. Some of them did get into the other programs. There was no concern over quality, functionally and physically, and conformancewise, those parts were considered new parts, equivalent of the normal part involved throughout the system.

The only thing was we had established a no rework policy for Mercury and we were upholding this.

As far as a degradation or downgrade of quality on the other birds, there was none.

MR. ARCHIBALD:

I might just add a couple of other thoughts to that.

We did, as I mentioned earlier, of course, have materials review actions on certain components like major assemblies, concerned our tank assembly, concerned basically our thrust structure that really you couldn't apply to perhaps other models of our missile.

We would overstamp the materials review paper work with "Project Mercury."

We've mentioned this before too so that we would know primarily where this rework occurred and what it consisted of. This was also reviewed by the final acceptance team, by the way, at time of rollout.

Emphasizing again that the materials were well within the engineering tolerances, of course, or we wouldn't accept them for use on any system. I think primarily the objective back of this was to emphasize to the people concerned the type of program that they were working on, not that the item would not have worked satisfactorily.

MR. BRYANT:

There is another comment on that too, Mr. Bailey, and that is while we had a parts selection and we did reject for Mercury and then turn around and use parts for the Atlas, I think that mainly what we were trying to do there, maybe subconsciously in some cases, was to gain experience.

After all, as explained this morning in one of the discussions, with an airplane you might get a possibility of 500 reports on how a piece of equipment works, and you gain the experience very rapidly.

In a missile you fly once and you hope you get all the data you need. On some of these parts we knew that they worked after early flights within certain tolerances, but sometimes we weren't quite sure whether we knew they were going to work ahead of time.

Therefore, they said, "Well, let's pick the center of the tolerance." Now this didn't mean that they were poor parts for other systems at all. I think the importance here is to cast your eyes right on the question of, what does failure analysis do for you?

When we actually had a failure then we started to really gain our experience to know really what we were talking about, and I think that is the real answer to that question.

MR. KEMPER:

Mr. Bailey, you want to remember that what I said just then was we didn't pick the best parts for Mercury. We picked the parts that were right in the middle.

Believe me, we had to have every inch we could get on both sides. This wasn't true in the weapons system. We had a wider tolerance to work with.

Mercury didn't get the best parts. It got the normal, good part.

MR. ARCHIBALD:

Perhaps a word of amplification on some comments that Major Jeancon made, and also Major Hanson, one of the things that we of course found was not only engineering changes but also changes in our manufacturing procedures, our processes, if you will.

We sometimes found that we would be willing to go along with a processing that was not, we will say, the most modern or the most satisfactory, perhaps, based on our experiences that we had.

We started the program 1955 to 1959 and up through 1963.

A lot of evolution has actually occurred to the state of the art, again using a hackneyed term.

We found that we were unwilling sometimes to accept on the Mercury Program certain procedures that maybe we would have been willing to live with if it was strictly a military ballistic missiles program throughout, and this again then upgraded the over-all manufacturing process.

MAJOR HANSON:

I would like to make one more comment.

Mr. MacNamara from Rocketdyne made a statement a while ago that the Mercury engine and weapons systems engines were the same. This was true, they went through the same line. The only difference was, again, we would look at the most nominal engine.

We actually looked at test data on the supply of engines they had at the time and picked again the most nominal, not the best, but the most nominal. We figured this might be the best engine.

This also, in the case of the engine systems, we did the same.

Again we were looking at the most nominal characteristics, test data.

MR. FILLMAN:

Al Fillman from Aerojet.

My question is really addressed more to Mr. MacNamara than the panel.

Everybody all day has been talking about special test procedures, special handling methods, special motivation programs. Rocketdyne is a major contractor on the program; Mr. MacNamara indicated he treated the parts as interchangeable and apparently did not take -- took a common approach to all the programs, rather than a unique approach for Mercury.

I wonder if you would care to comment as to the advantages and disadvantages which were found with regard to the specialized-type approach we have heard about today.

MR. MacNAMARA:

Well, I am sure there was an advantage in doing what you did.

Where we are building so many common types of hardware, if we start distinguishing between our quality and our quality procedures, we are going to get into considerable trouble.

And as far as our basic program was concerned, we are trying to get the maximum out of the weapons system too. I think this is really the key to this thing. I did mention this morning that the quality on this program has caused the cost to go up and when we have the fixed price contract, we find ourselves in an overrun condition and we think it is primarily because of the gradually -- gradual pressures and necessity to keep increasing these things.

I really believe that from our point of view where we are able to verify what we've got, we ran an acceptance test, a rather rigid test, maintenance of one level of quality which should be the best is the best approach to the problem.

COLONEL ANDRESEN:

Do we have a comment?

MR. HARGISS:

Hargiss, Rocketdyne.

I would like to answer Mac's comment that it is our desire at Rocketdyne to build the best rocket, not to belittle the Mercury Program. It is important. We think the ballistic program is pretty important too, because if it becomes necessary to push the button in defense of our country and something should malfunction in our engine, we are talking about a third of our population. It could be wiped out right now. They are both very important to us.

COLONEL ANDRESEN:

I think maybe we are confusing two points here.

I think sometimes we tend to confuse what a customer or user decides to do with the product, as opposed to the inherent quality that the producer puts in all his products. When you try to compare the two it is very difficult to reconcile them sometimes. So I think this is something to bear in mind as we discuss this particular question.

Frank, go ahead.

MR. KEMPER:

Well, you build an engine and I build an autopilot; they are the same on both vehicles. We don't have two standards of quality; nobody says we did.

I mean, as was said a moment ago, we don't have this luxury in the missile and space electronics. You have one, only one quality; that is the best you can do, and it is just as important to me, Mr. North American, that when they push that button that autopilot takes that thing to Moscow, not New York.

MR. FULTON:

Fulton for Aerojet.

I am asking from Rocketdyne also. I get the impression, I am not sure it is true, from what you say you had no special motivation programs for Mercury; that you had no different documentation requirements or detailed requirements in these areas.

MR. MacNAMARA:

This is correct.

For the Mercury engine and the Atlas engines, that is correct.

COLONEL ANDRESEN:

I think in fairness we should ask them this question: Did they know which engines were going to Mercury at the time they produced them?

MR. MacNAMARA:

No.

COLONEL ANDRESEN:

I think this is the question.

MR. HINCK:

I think the crux of this whole discussion was covered this morning by Ben Hohmann when it was pointed out that this program was conceived utilizing an existing product.

The quality and reliability for the Mercury was selected in, not built in, but designed in. It was a selected program, as many of the other components.

We select the best or the most nominal component at receiving. The engines were selected based on their data; the guidance was selected.

It was a selection program rather than a designed-in program and this was one of the requirements that in the event we were going on future programs of this type, that it should start in design, rather than as a selection task.

COLONEL ANDRESEN:

Mr. Bryant.

MR. BRYANT:

I would like to make a comment and maybe we can go on to another subject. And that is that we seem throughout the day, as I have observed the other panels and moved from one to one this morning, we seem to be getting into it again this afternoon, that the answer to the Mercury 100 per cent reliability of the manned flights was because we put something extra into the Mercury Program to the detriment, perhaps, to the rest of our product.

It is not the intention here at all; I don't think the purpose of the workshop is to bring this point out specifically, but to indicate that from Mercury we learned that we must do what Mr. MacNamara has stated, and that is that the product must be as reliable as possible, no matter where we are going to use it, and I think all we are trying to bring out here by your comments, as well as ours, on the Mercury Program is that we have matured a little more on the Mercury Program; we have discovered some of the things we must do as a routine, daily sort of approach in order to preserve the country, if it is a weapons system or our dollars, if it is further research and development into a new state of the art, space travel, that we must have.

We can say we are against sin and we are for motherhood, but what we are trying to do here is analyze if we can how did we get there and we are far from there yet, gentlemen, I assure you.

COLONEL ANDRESEN:

Do we have a question in the back?

MR. NADYHAL:

Jack Nadyhal, North American.

Someone said that there was a policy against using any reworked parts in the bird.

I find this a little hard to believe and I wonder if you would elaborate. It seems to me if this were a hard-and-fast rule there might be some disadvantage to it.

For example, in some cases if a part was found defective pretty far along in the process there might be more danger in doing damage in removing it rather than fixing it.

COLONEL ANDRESEN:

Dave, would you care to comment?

MR. ARCHIBALD:

Yes, as I mentioned earlier, we recognized this too.

In fact, in many instances we didn't have this lot of parts or components to choose from. We had some very definitely, especially designed or engineered items for the Mercury Program.

For example, one was the abort sensing systems, our tank regulator with basically the same design, but they had different tolerances, so there were peculiar items to the Mercury Program.

If you can exercise your memory you know these Mercury shots were rather widely spaced. Again recognizing this reason why we established the special materials review board, we did have problems but they were reviewed by selected people and after a thorough review, why, if a decision was made to repair it it was repaired, but if a decision was made to replace, that was what was done and we built a part new again.

This happened to Mr. Kemper here several times.

MR. KEMPER:

In the abort system which he speaks of, we have taken complete abort cans and a lot of dollars is in one of those; we had a glitch, even if it never occurred again, we never used that abort system and you're right, it cost money, but we didn't have to use the abort system either.

FROM THE AUDIENCE:

Not only am I concerned that it cost money, but it's entirely possible you might never finish the job.

MR. KEMPER:

Well, it could.

MR. TUTTLE:

There is one remark I'd like to make that where it became completely uneconomical or even relatively impossible to replace an entire unit, such

as, let us say, a missile tank, if a repair was made, an extremely high level of engineers, and management, and customer people analyzed it very thoroughly, even to the point possibly of backing up the opinion of these people by some special tests and thereby proving beyond any question of doubt that the reworked part was sound.

FROM THE AUDIENCE:

Then this wasn't a hard-and-fast rule?

MR. BRYANT:

No. I think perhaps what we are really trying to explain here is that again it was a learning process. At the time the Mercury Program came along we had X amount of experience on how far we could rework. We had standard rework drawings and an MRB board that made a decision that, "Yes, rework it in such and such a manner."

If we didn't have a rework drawing, when Mercury came along we still were deficient in the amount of experience on whether or not that rework actually was satisfactory, so all we were really doing was placing the rework decision at a higher level and in many cases turning it down for the lack of experience and even though we had had perhaps a little bit of experience that worked all right before.

MR. STEVENS:

Stevens from Aerojet.

I am particularly interested in the rocket engines, and we talk about a propulsion system; we are talking about not only the engines but the tankage too.

My observation here today is that we have two different standards; that when you talk about GD/A you are talking about something that may not apply to the engine, and it appears to me the engine is a vital part of this propulsion system. I am just listening to the North American or Rocketdyne people, and they appear to have entirely a different standard on some part of the propulsion system.

MR. HANSON:

Maybe I could answer.

COLONEL ANDRESEN:

Yes, go ahead.

MR. HANSON:

A couple of things enter in here. Engines do lead the aircraft or the rest of the system by quite a period of time. As we have seen throughout this program it is a learning process; we have been putting these things in safety programs, which was maybe first designed in '59, but I think we really came up with our first work stages in about '60; really got them in the contract, so that these -- this concept was not introduced into the engine maybe as deeply as it was in the missile.

However, Al has brought out a point I think that you should really think about. It is more selection, it is selection. We selected here; we selected maybe a major component where on the missile system we maybe selected a lower level at a lower level, select down to the interverter -- interverter, what are some more of them?

MR. HINCK:

Actuators.

MAJOR HANSON:

We selected a lot lower level here than we did with the rocket engine. That is also because of the learning process.

FROM THE AUDIENCE:

I think the thing we are particularly interested in here, for example, in our case we are just starting up in the Gemini Program; we are faced with the same type of problems you people are faced with right now; we are getting into designing, motivational programs, the full ball of snakes that has been discussed here.

I think these things are expensive and it is real important in this workshop to bring out both points of view. I do feel that what Rocketdyne has been saying is another point of view. They have treated the thing on a common basis; we ought to hear about this because many of us are faced with this.

COLONEL ANDRESEN:

Yes, Colonel Eickel has a great deal of experience in this business and I am sure his comments will be very worthy.

FROM THE AUDIENCE:

I can't argue with what Mr. MacNamara says about his quality control. I would not agree though that the same philosophy was used in acceptance of the engines as in replacement of parts. We used the same philosophy.

The engine boxes, we reworked them; we used some new ones, in the case, if we thought this would increase the over-all reliability of the flight.

The philosophy was one that was in force perhaps after acceptance, and this engine was at that time considered as a GFP vendor item insofar as at that time initially, give Mr. MacNamara his reliability that was higher than the over-all reliability of the system, and we were further down the line on producing the engines.

A lot of these engines were already produced when we started this philosophy. I can't agree that the over-all philosophy of the Mercury team was the same, at least with the weapons system. I think here is a specific case where the weapons system did benefit from increased concern on the part of the Mercury team.

MR. BRYANT:

Colonel, as I see what has just been brought out, it is really the point of what we are trying to get at today. Here is a case from Rocketdyne over a longer period of time that had been able to by greater tests, ability to know what they had in their product; had established their standard of quality for all engines or their product and therefore they did know what

they were putting out. They had their usual problems like all manufacturers do, but here we were further along in the system and we are yet to gain what they have already gained.

I am only speaking of this as a philosophy. Major Hanson brought it out and someone else did too, that it is a sequential thing, and the Mercury Program, as far as the system in its entirety, we have to gain what the engine manufacturer was able to do earlier.

COLONEL ANDRESEN:

I think, gentlemen, that it is important to state that as far as Air Force program officers are concerned, they attempted to maintain a uniform quality of standard among all components which make up this system, recognizing that a chain is only as strong as its weakest link.

However, you must also recognize that many associate contractors are involved and their approach to how you obtain this objective may be different in technique and colored by time.

As a result, I think that it is fair to say that we do get these differences of management philosophy pertaining to these particular subjects. However, this is the purpose of the workshop, to exchange these ideas and pick up the key points that may be observed from each of the several operations, use those which are applicable to our particular programs and in the particular time sequence that we find ourselves now in; and therein I think lies a little lesson that we would like to put on this particular point.

I think we're ready to start again.

FROM THE AUDIENCE:

On your check-off list there (indicating) you have "Contamination Controls."

I assume that means both chemical and foreign particles.

In the area of foreign particles -- maybe I should direct this to you, Dave: Have you specified by micron size and by population, and if so, to what degree or what particle size and what population size?

Just give me a range.

MR. ARCHIBALD:

When we first started off in this we started off 10 micron size for hydraulic systems. That is what was specified.

Population at that time was not specified, however, we found that it was very, very important that we pin this down.

We had 150 microns in the propulsion system. I am talking about the oxidizer and the fuel system.

We later found out that that was not necessarily required, and now we are up to 1,500 microns in one direction for certain types of material. This also holds true, of course, with the hydrocarbons and other contaminants that we might be concerned with.

This is a coordinated specification that all the ballistic missile contractors are presently using. This took some doing too.

MR. BRYANT:

It sure did.

FROM THE AUDIENCE:

You mean you've got it all licked?

MR. HOPMAN:

No, we haven't got it all licked, but we do have it pretty well licked. We've got it defined, and this is the important thing. I think I brought out, that we had, previous to the Mercury Program, effected a series of compromises. We did have some specs, but actually probably didn't pay as much attention to them as we should have. With the advent of Mercury Program, we had to sit down and really define what our specs were going to be, and this we did.

In some cases we found that we could raise the specifications and if I remember, particle size ran up to 500 microns and 1,500 microns in the lint area, if you are familiar with that.

To achieve this, we had to develop new techniques, get new equipment, sonic cleaning tanks and drying ovens, clean rooms, things of that nature.

Also, our methods of inspection differed. Previously we allowed both a wipe test and a solvent extraction test, and these would give greatly varying results, so we had to pin these down. I think we are on a pretty stable footing now, and know what we are doing. We have our parameters defined and are adhering to them.

COLONEL ANDRESEN:

John, would you care to comment about some of the difficulties you had on that cutaway?

MR. HOPMAN:

Yes, I have a cutaway up here, a cutaway duct, and it contains an omega joint and a typical bellows joint. From this you get a pretty good idea of the difficulty of cleaning joints of this type.

This is the kind of traps we were confronted with in attempting to clean. Of course these components that we were running through our cleaning process, we had to assure ourselves that they were clean. I might mention that the reason this duct is cut in half is that this was a destructive test that we accomplished to determine whether our cleaning methods were proper and would do the job. We cleaned this duct using the procedures that we had set up and then cut the duct in half and checked it to make sure it was thoroughly clean, and we found it was clean.

COLONEL ANDRESEN:

Thank you, John.

MR. HOPMAN:

The gentlemen mentioned about chips here.

There are several methods of cleaning the chips out and in this case we found that using a sonic cleaning tank is a very good method of dislodging chips and then, after that we used a closed loop flushing method to clean all the contaminants out of the duct.

Also, as we are fabricating the component, we use a method which we call "fabricate clean," and every time we make a part or conduct an operation on a part we send it to the clean room or at least run it through a cleaning tank, and this enables you to clean the chips out as they occur and doesn't allow any great accumulation.

We found out very early that if you allow all the chips and dirt to accumulate and then tried to clean it all after the component was complete, sometimes you were unable to clean the component completely.

So we clean these in detailed parts and after operations in many cases.

COLONEL ANDRESEN:

Thank you.

MR. TUTTLE:

I wanted to stress the fact that we did not have two standards of cleaning in the plant, one for Mercury and one for other birds, but we had to raise the entire level of cleaning throughout the factory in order to accomplish the reliability that we needed on Mercury.

COLONEL ANDRESEN:

Thank you.

Do we have a question over here?

FROM THE AUDIENCE:

As part of the cleaning problem, how did you clean your autopilot and electronic systems? Did you use sonic cleaning?

MR. KEMPER:

You will have to define at what level.

FROM THE AUDIENCE:

First built-up level.

MR. KEMPER:

First word?

No, we do not use electrosonic cleaning in the birds. We have the normal glove routine and all that sort and we use flow soldering on our boards; they go through a hand wash and light box where we check it for dirt and stuff, and then we conformal coat. After we get that board conformal coated, it is like most of the fungus preventive things, we more or less get away from the cleaning requirements, as such, because you can no longer affect the circuitry because of this conformal coating.

We do go through a very extensive vibration testing and we do it at the top level.

Maybe we are redundant, I don't know. There is some feeling that we are, because we take it, we tear it down and look at it; then we test it all over again.

There is a question of how far do you go with this.

FROM THE AUDIENCE:

This is on production birds, flyable?

MR. KEMPER:

We check all instruments under vibration.

COLONEL ANDRESEN:

Do we have a question in the rear?

MR. NADYHAL:

Nadyhal, North American.

Could you tell me whether there is any brazed honeycomb panel structure?

Does the Mercury air vehicle contain any brazed honeycomb structure?

MR. HOPMAN:

No.

COLONEL ANDRESEN:

No, no brazed honeycomb structure on the Mercury.

FROM THE AUDIENCE:

How about the high-pressure piping, are the joints brazed, welded or mechanical?

COLONEL ANDRESEN:

Mechanical.

MR. BRYANT:

I would like to throw out a question in the audience.

Is there an increasing feeling at your various plants that welding of the tubing, high-pressure tubing, is a requirement to overcome your leakage problems?

FROM THE AUDIENCE:

Yes, if I may comment, all of our lines that we are doing on the Saturn, for example, are all welded construction, fusion welded.

MR. BRYANT:

At the assembly?

FROM THE AUDIENCE:

No, no.

No, in fabrication.

MR. BRYANT:

I think this gentlemen's question was at the top assembly level.

FROM THE AUDIENCE:

I misunderstood.

MR. SIMKINSON:

I might say, Elwood, we are doing this on Gemini spacecraft, all welded construction.

As you know, Mercury gave us a few headaches in this area.

MR. BRYANT:

The reason I am interested in this is this is a very definite problem that we have had and still have, and I think all the aerospace industry is faced with this problem and we'd like to get some information too, you see.

FROM THE AUDIENCE:

Aren't the final connections generally brazed?

MR. SIMKINSON:

Yes.

FROM THE AUDIENCE:

Brazed?

MR. SIMKINSON:

Yes.

MR. HOPMAN:

Do you have a sleeve in or outside of the joint?

FROM THE AUDIENCE:

Yes, and then brazed. It is induction heated during the brazing, isn't that correct?

MR. SIMKINSON:

Induction heated.

We plan to be able to remove a valve by debrazing, I hope.

MR. TUTTLE:

Do you do any special brazing of the brazes, X-ray and so forth, after brazing?

MR. SIMKINSON:

Yes, they are.

MR. TUTTLE:

X-rayed?

MR. SIMKINSON:

I cannot tell you what the process is.

MR. BRYANT:

I might have mentioned it; it might be of interest here, but I think that one of the gentlemen here mentioned that we have a long ways to go.

I guess it was Major Jeancon -- a long ways to go in changing our specifications.

We on the Atlas used for a good many years standard B nuts in fittings. We finally found that the controls on such commercial pipe, you might say, was completely unsatisfactory and we recently just wound up a very extensive, hundreds of thousands of dollars worth of changing all our lines and applying special specifications with special purchase orders out to the vendors to manufacture B nuts to a new criteria. I think this is only a typical example of what we are faced with in the aerospace industry today.

We are still learning what we have to do in the welding, that is why we are interested in the welding of lines. We are not sure whether this is the answer, but at least it is one answer right now, I hope.

COLONEL ANDRESEN:

We have several questions.

MR. HOPMAN:

I would like to add one comment to that, if I may.

This was another problem, as far as chips were concerned. We found out that we might take extreme care in cleaning the part at the detailed part or the component level, particularly a tool, and finally the installer got his hands on it, put it together, and the threads on the AN nut or the B nut were so coarse that as he tightened up this thread, little curls ejected from the thread and went into the system and therefore contaminated all of our system on hydraulic, pneumatic and helium lines.

We finally wound up with quite an extensive rework on all of the AN fittings we had in the plant. We had to take all the threads individually and burr all the threads to make sure there were no loose burrs on the threads.

This also was expensive.

FROM THE AUDIENCE:

I want just to comment on this welding about which he asked.

I am from Aerojet; we are going to more welded joints. I am talking about the engines now and these are particularly, we find them, a tendency toward the contract we have with NASA and particularly when you are talking about -- for instance, M-1 is using a tremendous amount of welding in the final assembly area.

MR. BRYANT:

It is a definite problem and we haven't found the answer, we admit it.

FROM THE AUDIENCE:

Mr. Bryant mentioned they did several hundreds of thousands of dollars worth of R&D work coming up with new specifications for those things.

Is this proprietary?

MR. BRYANT:

I didn't make myself clear. I say, this change which we had to go from the standard AN fitting, which we had been using in B nuts, involved establishing our own criteria, which was an improvement, you might say, in reliability and control, tighter controls on the material, the dimensions and the chemical content of the complete Mercury.

In other words, it was a control specification on that particular item. You do the same thing in your place when you find you have to. This is such a big one --

FROM THE AUDIENCE:

But that is not proprietary, but would be available to the industry on request?

MR. BRYANT:

This wasn't development. We already knew these kinds of things were needed.

It was just we had to apply them in this particular spot.

MR. ARCHIBALD:

This information, by the way, is available in MIL-F-5509, Amendment 7, Revision B.

FROM THE AUDIENCE:

The question I have, while the welded fittings and plumbing in the bird is far more reliable, less leakage, what type of precautions are taken wherein a component vessel with a brazed fitting or brazed section has the welding hookup to the plumbing of the bird in close proximity to the original braze, which while the original braze was certified and correct, what precautions are taken to prevent damage of this in the subsequent welding to the plumbing?

MR. SIMKINSON:

If that was addressed to me, I am afraid I missed it.

FROM THE AUDIENCE:

In other words, say we have a vessel, pressure vessel; the fitting is coming out; rather than being an AN fitting is a brazed fitting, but the hookup area to the plumbing of the bird is in close proximity, an inch or two, to this original braze on the component. What precautions are taken to prevent damaging the original braze by the subsequent braze or welding?

MR. SIMKINSON:

I am trying to think of a specific case and I don't think I am that close to the hardware yet.

I am sure this will have to be considered.

What you are thinking of is heating your first braze and destroying the second one?

FROM THE AUDIENCE:

If you rebraze your rebraze, melting temperature is higher than your initial temperature brazed joint -- I don't know --

MR. SIMKINSON:

I would only say there that obviously we just can't do it. We will have to use a heat sink on the first one, a wet rag, what have you, some method to keep -- to make sure.

That is a good point; I will sure keep it in mind when we get to it.

MR. BRYANT:

Getting back to a comment that was made initially, the flow times were longer for the Mercury Program. Now this is proportionate for our quality control activity too.

COLONEL ANDRESEN:

How about in the electronic area, Frank, do you want to comment on that?

MR. KEMPER:

I think Frank Babler is in the audience; I think he can give you an exact number in our ratios in electronics.

FROM THE AUDIENCE:

I think it depends strictly on what we were doing. In the assembly fabrication area electronics runs 6 to 1; in the testing when we are running a canister, Frank may use one man to run the test and I use one inspector; it gets down to 1 to 1, on the final gyro package.

I might say, there was a little difference in the activity, I felt, where it hurts the worst, and that is where it's a Mercury item; we were big, everything we did for Mercury, always people looked at it hundred per cent and this is the concentration of the people we had. We might have an air weapons system bird that was running a test on gyro; he would make surveillance of this if it was the Atlas or Mercury package. He was looking over my shoulder.

FROM THE AUDIENCE:

What about pay scales, how did inspectors rank, compared to technicians!

MR. BRYANT:

As a general policy at GD/A, we attempted in all cases to have the inspector equally as skilled as the craftsman who is working.

MR. ARCHIBALD:

This holds true, for example, in our soldering certification program, the training for certification program for the installers, electrical connectors, inspectors are subject exactly to the same training and testing.

FROM THE AUDIENCE:

What kind of relationship prevails?

Do the production people regard the inspectors as a damn nuisance or do they look up to them?

MR. ARCHIBALD:

Occasionally.

MR. TUTTLE:

I would like to answer that from a final assembly and checkout standpoint.

I believe at GD/A we have a very fine working relationship between the quality control people and the factory people.

We understand why the inspector is as he is and we are willing to go along with him, but there is very little, really, there is very little animosity. We are all working together.

FROM THE AUDIENCE:

With all due respect, may I ask, are you fairly confident that this is as true on the working level, among the men, as it is in your own mind and on your own level?

MR. TUTTLE:

We think so.

MR. KEMPER:

I have been working with inspectors in aircraft and missiles for 30 years and I have seen more respect for the position of the inspector on missiles and space work than ever existed in the aircraft industry.

When I was in aircraft it was "God damned inspectors." It was all one word, but now you don't hear that, and these guys are pretty close together.

FROM THE AUDIENCE:

What did you do to accomplish the changes?

MR. KEMPER:

Speak to the inspectors.

MR. BRYANT:

I would like to make one comment from a management level, getting into policy, and again it was touched on in a very good general way this morning; that is that you accomplish this primarily in your attitude of top management and working down in levels of supervision. I am in the top management area of operations, and my attitude is, "I don't need inspectors.' if you get my message.

I welcome them just like I welcome a timekeeper. I welcome them, they are an assist, but I want everyone who works for me to do a good job. He should look for the inspector to help him and not be in competition with him.

I think as sure as Dave says, we had certain problems, and usually it is an individual personality problem.

One of the things I think, that is in the aerospace business in missiles, I think the message is getting to the people that it is necessary to do a good job and we have to give them a micrometer; we have to give them a voltmeter, some sort of tools to do their job, and they look to the inspector as a respected tool, and I don't mean that as any disrespect, but I think there is the spirit of working together more than there was years ago in the old production line sort of thing.

COLONEL ANDRESEN:

Gentlemen, it's time to bring the session to a close. I want to thank the audience for its spirited and constructive participation and I want to thank the panel members for their frank discussion on the topics that were brought from the floor, and I hope that the session has been as profitable to you as it has to me.

I thank you for your cooperation.

(Applause.)

(Whereupon, the afternoon panel discussion on Manufacturing and Process Controls was adjourned at 3:45 p. m.)

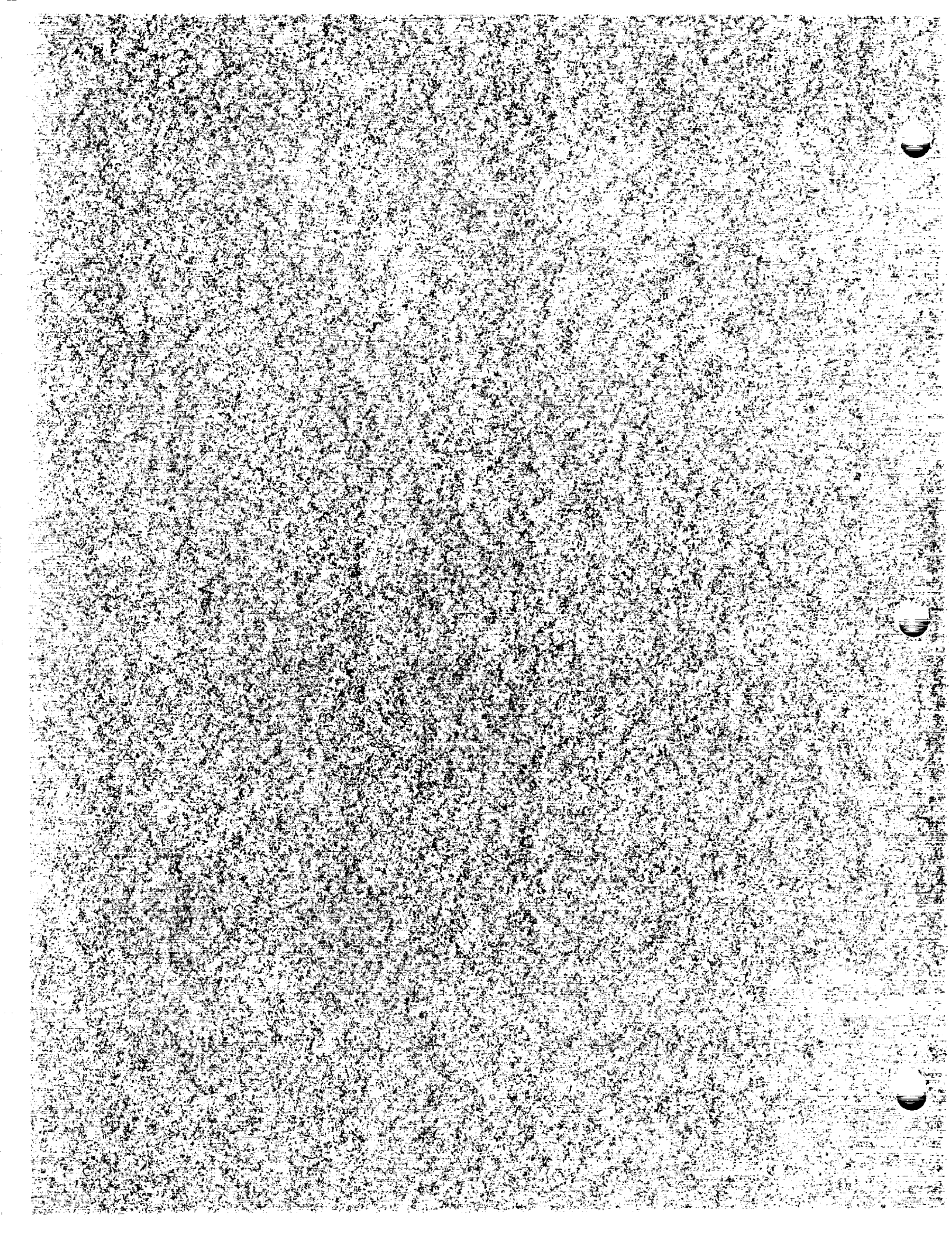
Subject Test Control

Time 1:30 to 3:45 p.m.

Location Sunset Room

The test control panel will discuss such tests as receiving and inspection, qualification and demonstration, and factory vehicle acceptance; flight and Air Force test controls; Aerospace Corp. technical direction; and failure analysis and data control. Panel members are:

Mr. G. M. Preston, NASA, Chairman
Mr. W. J. Maloney, Astronautics, Coordinator
Mr. W. W. Withee, Astronautics, Coordinator
Mr. R. Gilliland, Astronautics
Mr. D. W. Heagy, Astronautics
Mr. R. W. Keehn, Astronautics
Mr. L. I. Medlock, Astronautics
Mr. T. J. O'Malley, Astronautics
Lt. Col. P. W. Richardson, USAF
Mr. J. F. Wambolt, Aerospace



MR. WITHEE:

Good afternoon, gentlemen.

It is my privilege this afternoon to invite you to this session on Test Control on the Mercury-Atlas Booster Reliability Workshop.

It is also my privilege and honor to introduce your chairman to you at this time. I don't think many of you need an introduction to him, particularly if you were in the morning sessions. You saw him on the film rushing through the crowd for the president to hand him his award. Normally he is on time, I guess nobody told him that he was going to get that award.

However, briefly, our chairman for this session has been with NASA for twenty-four years and during this period has worked at the Lewis Research Center and the Langley Research Center.

He went on the Mercury program in 1958 and is presently manager of AMR operations for the Manned Spacecraft Center at Houston.

I think his experience and background certainly qualify him very highly for his job today as chairman and monitor of this session.

With that I will turn the meeting over to Mr. G. Merritt Preston.

MR. PRESTON:

Thank you, Wally.

I would like to philosophize a few minutes here before we start with the main program.

You have heard a lot of discussion today about the teamwork of this project in Mercury and I think the reason for the repetition of this statement was because it truly was a terrific teamwork effort. But I think you have to realize what teamwork really is and I feel that there are probably two vital things that create teamwork and the first one, of course, is the management that will delegate authority and responsibility and assign it in such a manner that the people know what their jobs are and once they have assigned this job, that other people try to help other people do their work, but trying not to invade on their job of doing their own work.

So this ends up with a mutual respect for the individuals involved in the program and I think much of the success of Mercury was dependent on the fact that NASA respected the Air Force, Convair and their abilities to provide us with a booster that would perform the task and as such we did not try to supervise them or monitor them in extreme detail.

We were interested in the major problems and they willingly told us about the major problems.

So I think that teamwork is dependent on delegating authority and letting a man do his job after you have delegated it.

The second item I would like to discuss a little bit is about what testing is and how you do the testing.

I have been in testing for twenty-four years. In fact, my whole professional career has been spent in testing and one of the most important things to develop in testing, I think, is what I call technical honesty. It is pretty easy when you are conducting a test to disregard test points because these oddball test points only mean trouble. They only mean work on your part and you have to explain why they are odd and usually the general tendency is to say that the data is no good because you can't understand them.

Well, the truth of the matter is usually because you haven't been able to explain what the trouble is. It is not that the data is no good.

I think to obtain the reliability that is necessary, you have to pay very particular attention to these data points that don't look good because they are the ones that are really important. The ones that are normal are the ones that look good, they are that way because you expect them to be that way.

Any tendency to disregard data and declare it is bad data is probably the first step to unreliability.

How do you obtain a good test engineer?

I think first of all you have to have curious people. They have to be curious to look into all of the results that are being produced, like I said,

the good ones and the bad ones, they have to be very objective in how they run the tests so that they are truly trying to reveal the results that you are looking for.

Now, intuition is a very large factor in testing, particularly in the functional testing that we do at the Cape. A lot of past programs have used statistical methods of testing to develop reliability. The Manned Spacecraft Center has more or less gone away from this policy of statistical reliability testing and in its place they have substituted development testing and emphasized developmental testing.

We feel that you obtain reliability not by accumulating a large number of statistics on failure rates, but by testing and every time you find a malfunction, you correct it and finally after you have corrected all the malfunctions, the thing will be reliable. So we are spending most of our energy in developmental testing rather than statistical testing.

Now, there are a few things that I would like to point out before we go on.

The session will be composed of seven short discussions of about five minutes by each of our speakers here. To save time I will introduce the speakers as they are ready for presentation. If you have any questions concerning the particular subject being discussed, we would welcome them at the end of that particular discussion. However, as a general nature I would appreciate it if you hold it until the end when we can have a general discussion.

Now, our first subject today will be given by Joe Wambolt of the Aerospace Corporation. He will discuss vehicle testing for reliability as the Aerospace role in this portion of the work.

I first ran into Joe down at the Cape where he was the lead engineer on the Mercury program for the AMR Aerospace office. He was assigned to this job in about December of 1960. He was assigned back here to San Diego in September of 1961 to be the Aerospace representative here at GD/A.

Joe, will you go ahead for your presentation?

MR. WAMBOLT:

The board up here says "Aerospace Technical Direction," but I would like to cover a different subject and talk about Aerospace's role particularly in the field of testing and then talk about a couple of approaches that were developed by the contractor, Aerospace contractor team as work progressed.

As a technical management test, or management for the Air Force, Aerospace got involved heavily in the testing program and in the area of establishing ground rules for the test program and before this could be done, a fundamental policy had to be developed to govern our testing and the policy decided on was that of using milestone testing or, you might call it, successive testing, where each component or subassembly would be tested as a unit and successfully pass all tests to a point of completion and that subsequent testing on that unit would never be considered as adequate retest.

If that should fail, using this fundamental policy, we have established ground rules as the program progressed covering component testing, to make sure we had subsequent testing on the vehicle, and the final demonstration or composite test on the vehicle before it was developed.

We also established ground rules for independent testing at AMR both in the laboratory and on the vehicle and went further and established criteria for retesting if the part should fail and the degree of rework allowable in certain areas, particularly in the area of electronics.

The second area where we got pretty heavily involved was that of procedural surveillance. There again basic ground rules established were that all activity concerning the vehicle would be controlled by procedure and once this was accepted, we felt an obligation as a company in view of ground rules to review these procedures as generated and go along with them.

Data analysis or review, where the contractor generated material and data, was independently reviewed by Aerospace Corporation personnel and an objective conclusion regarding this data was given to the Air Force.

Now, as the program progressed, the team relationship that you heard this morning stressed was further developed and we jointly developed approaches toward testing that, well, they were pretty hard to define at the beginning of the program, but just grew.

There is nothing shocking about them, they are probably truisms, but they are things that we stressed.

First, in the field of detailed engineering, here we had a lot of agonizing daily attention to situations and problems regarding the vehicle, whether it be in the factory or at the pre-fab or in the hangar. This amount of attention, every situation that came up, was both necessary and rewarding and we found ourselves analyzing not only systems data but as our chairman hit upon a moment ago, we were also analyzing anomalies and glitches which by themselves seem to be meaningless, but analyzed by the entire team and some attempt made to the best of our ability to justify their being and to try to determine what their cast and effect would be on the system. If they were defined as a characteristic of a particular subsystem, then they were re-evaluated in terms of a repeated characteristic to see if it would be acceptable to the rest of the system and this introduced to us a new concept of data analysis and testing which might be called trend analysis and this was very heavily stressed during the latter portion of the program, where every characteristic once defined was expected to repeat and any parameter, any measurable change in a particular parameter that was observed, was watched to see whether or not it was a sign or possible sign of degradation of that system, even though space limits we established were to be far exceeded.

The second major approach that developed, this may be a result of testing more than anything else, but I call it contemporary testing of procedural housekeeping.

During a program as dynamic as Mercury was, an aggressive trade analysis program was necessary and configuration techniques had to be developed and with both of these mechanisms in full operation, a tremendous amount of configuration changes and modifications were necessary and had to be implemented effectively and efficiently. As an example, in the Mercury program in the factory a flight control system check off procedure was changed 59 times during the Mercury program and was completely revised.

Now, this tremendous task of housekeeping of the procedures is very easily overlooked and they have to be looked at by all the contractors in Aerospace and Air Force persons or all participants in the program to see if they are compatible with the change and also that they adequately test the configuration.

Areas of failure analysis and configuration, I am sure, will be discussed by other panel members.

That concludes my talk.

MR. PRESTON:

Anybody have specific questions directed to Joe or preferably hold them to the end?

(No response.)

MR. PRESTON:

All right, then, Dan Heagy, next to Joe, of GD/A will discuss qualification and demonstration testing, which includes environment, functional and unified test plan.

Dan has been with the Mercury program since February of 1959, in charge of the systems engineering group at GD/A, which is responsible for test parameters, test procedures and test qualifications and test management. He is presently chief of test procedures and integration.

Go ahead, Dan.

MR. HEAGY:

The first part of my subject that I would like to speak about is the environmental test program.

As you have heard, the Mercury was fundamentally an Atlas D operational vehicle that was modified to a minimum extent for the specific purpose of launching the Mercury capsule and as a result, drew heavily upon the already obtained data from the qualification program that was very

thoroughly enforced on the D weapon system and also benefited substantially from the flight test experience of all earlier series, as well as the D series.

However, to assure that everything was properly bedded down and that there were no oppositions, a thorough review was undertaken by the design engineers associated with their components and systems to review all existing test history associated with their hardware.

This review was then subjected to thorough scrutiny on the part of Aerospace, Air Force, and GD/A to make doubly sure that all possible weaknesses, anomalies and so forth were answered.

I should point out that the qualification that was performed on the Atlas components was done to design levels that were increased over the flight level by a safety margin. So that there was even greater assurance that the equipment would behave properly and satisfactorily when subjected to the actual flight environment.

There were a few modifications made to the Mercury, however, from the basic D series bird. One of these was the autopilot. The D operational missile used a round electro-mechanical type autopilot where it was selected to use the all-electronic, square-type autopilot for the Mercury vehicle that had been developed as part of the E and F series weapon system. It was decided that this system would be given a rather severe series of reliability tests to assure that this program was properly carried through and it required confidence established and the design verified.

The other system that you have heard about that was developed specifically for the Mercury program was the abort sensing and implementation system.

Since brand new it was desired again to perform an exhaustive test program to assure satisfactory performance would be carried through. So this reliability program which we refer to at Astronautics as a search for critical weakness program was instituted.

There had also been a program of this nature established for a large number of other components of the Atlas that automatically picked up the

priority afforded the Mercury program in the urgency to secure insurance that this was completed to the first manned flight.

Contrary to the way that most qualification tests had been performed in the past, the search for critical weakness program combined tests.

Normally in our program, at least, the components had been subjected to one environment at a time. In this case we combined several of the environments, such as vibration, and combined it with temperature and also overstressed the items beyond the design level to higher levels of G's, acceleration, vibration, temperature.

The production evaluation test program that was in use throughout the weapons program was further extended to incorporate the Mercury components. This is a program that, periodically on a random basis, selects production hardware and resubmits it to the design level of environment of the operating variety. It picks up again retests of the ability of the equipment to withstand vibration, altitude, temperature, humidity, but does not generally reach out and retest the equipment to salt atmosphere, fungus, sand and dust and the climatic environments.

We also have a program at Astronautics, under way for some time, that is referred to as a production vibration program. In this program 100 per cent of the components of the electrical and electronic variety, usually at the black box level, but sometimes at the assembly board level, are subjected to a hot shake. This hot shake we refer to is a fired up configuration of the equipment with critical parameters being monitored while the equipment is actually undergoing vibration. This vibration level has been selected to expose workmanship defects and process errors.

The next major element of testing is one associated with the functional checkout of equipment. We have felt here for a long time that a totally integrated program of parameters and their associated tolerances should be put together in one centralized location which we refer to as our parameters document to define the entire functional checkout program from receiving inspection through the last checks made prior to launch to assure that testing gets more end to end as we get out to the field and to complete our assemblies systems and also a widening of tolerances as we go from the point of receiving inspection to utilizing the full amount of tolerance when we get to flight.

By having a central definition of this test structure, it forms the framework for all the test procedures that are used throughout the various phases of assembly and test. Also the tolerances associated with these tests are defined such that all data obtained during the checkout can be evaluated against a source document that is kept up to date and change control and released through the engineering release system.

Since the Mercury was fundamentally a D series Atlas with very few changes, a supplement was made to the parameters document to define all those differences associated with the Mercury-type vehicle so they wouldn't get lost, reduce the possibility of error and permit concentration of attention on those things that were different or where additional controls were required.

Another point of emphasis was to submit to the customer his approval on acceptance test plan for the final checkout of the missile and the criteria that determined the acceptability of the vehicle for delivery. So this plan was prepared and submitted to the customer for his approval and was again under change control.

Joe had mentioned our emphasis on procedures. Other than having it locked together with a parameters document so that the tests that were required were actually accomplished by the procedures, they again were put through a release control and configuration control requiring design approval prior to their release.

In addition to this, there was a thorough review made of all factory and field checkout procedures not only by General Dynamics but particularly by the Air Force and Aerospace to make sure that the scope of the test, the technical adequacy and accuracy of the test and the assurance that the procedure, in fact, did match the hardware configuration, was true at all times.

We have learned over the many years that we have been associated with testing on the Atlas and as emphasized by certain of the controls that were put in for the Mercury program, that it is even more and more necessary to put together in a centralized and controlled form the test plans for all types of testing, whether it be environmental, developmental or functional.

This has advantages other than just being able to show yourself and your customer what all the testing amounts to and make sure it is all concurred with, but it provides an even more significant point of view in terms of reducing duplication of effort, unnecessary expense, and I think even more important, the ability to get the test program that is planned done and executed on time by a centralized way of bringing back to management's attention those places where deficiencies are found in the equipment under test or actually deficiencies in the tests that are planned to get expeditious and decisive action.

This type of program is now in being and is being implemented at Astronautics.

Thank you.

MR. PRESTON:

Dan, one of the points that you brought out that I think was novel, at least novel today, is this critical weakness study in which you expended a terrific amount of effort when the Atlas was adapted to the Mercury.

Does anybody have a specific question here?

MR. EVANS:

Yes. My name is Bob Evans, from Martin-Denver. I am interested in how your final test program compared with the one you started with. Did you find you had to get more stringent or did you find that you could relax over your original concept?

MR. HEAGY:

Are you thinking in terms of tolerances or the scope of the test?

MR. EVANS:

Magnitude of test.

MR. HEAGY:

Quantity of tests?

MR. EVANS:

Quantities.

MR. HEAGY:

I wouldn't say that it changed substantially. There were a few things that we picked up that maybe were not as adequately covered when we got started. For instance, as a result of the problem we had on 10-D when we didn't separate the booster, we never did really verify why we didn't separate the booster, it is being still, although a simple system, interfaced with additional controls. We put in other controls. We put in other controls to insure that the systematic power that initiated the system was strengthened and actual physical inspections to make sure that the connectors were properly in place.

I would say we increased the scope of procedural coverage, but I don't believe that I can say that we did a great deal more testwise to a Mercury booster than we did to the regular Atlas program.

MR. EVANS:

What I was concerned about, at the outset of your man rating program, were you optimistic or pessimistic about what tests you have performed?

MR. HEAGY:

Well, we were optimistic about the ability to launch the man successfully.

MR. EVANS:

I am not communicating.

MR. HEAGY:

I am afraid not.

MR. EVANS:

I guess we are all concerned with the fact that we had a man in the capsule. Do you find that you ran more tests or less tests because of the loss of the components?

MR. HEAGY:

You are thinking, then, of the frequency with which we ran tests?

MR. EVANS:

Yes.

MR. PRESTON:

I think he is wondering if you were going to wear the parts out.

MR. HEAGY:

I wouldn't say we were concerned with wearing the parts out.

Tom can help me on this, but he mentioned yesterday, if we had to scrub as we did several times for the weather, that there were reassurance tests performed again to make sure that everything was working satisfactorily to take the additional time that we had and make sure everything was possible. If there was a doubt in any mind at all on the system of the bird, we would rerun the test.

MR. PRESTON:

I think in general, if the system isn't reliable to determine its function of readiness, then there is something wrong with the basic design of it. You shouldn't design that much margin in the flight.

I don't think we should pursue this very much now. Let's come back to it, do you mind?

MR. EVANS:

Not at all.

MR. PRESTON:

Let's go on to the next panel member. He is Russ Medlock of GD/A. He is going to talk to you about the supplier and receiving inspection tests.

Russ was the chief of support quality control in the 59-60 period. He developed the quality control procedures for the spares provisions of Project Mercury. He is presently manager of quality control.

Won't you go ahead, Russ?

MR. MEDLOCK:

Yes, thank you.

In the area of supplier and receiving inspection, especially receiving inspection, I think the general concept of many minds within the company is that all we do is kick the box, and from the supplier viewpoint I am sure he feels that we test his parts to death.

Well, lying between these two extremes is actually the area of truth and I feel that maybe I'll just hit the high points of what we do and if there are some specific questions during the later discussion period, we can talk about the details of receiver or supplier testing.

Inspection testing of supplier items varies with the category or type of the part or component.

Factors such as complexity, critical nature or special test requirements actually are used to determine test requirements.

For the purpose of this discussion I have divided supplier items into three categories: piece parts, component assemblies, and end items.

All functional piece parts used in production at Astronautics are tested to predetermined test requirements 100 per cent at the receiving inspection level. The only exception is low-cost, non-functional hardware.

Test requirements are specified in receiving inspection test procedures that have been developed from part number control drawings, government specifications, supplier specifications and Astronautics reliability test specifications.

Test requirements for piece parts over the time period of the Mercu program have increased or decreased depending upon problems encountered and experience gained.

In the area of component assemblies, these are covered by Astronautics specifications -- I should say specification control drawings or book specifications which outline supplier and receiving test requirements.

Acceptance test procedures are approved in advance and by this I mean a supplier's test procedures are approved in advance by Astronautics.

Astronautics source inspection is specified on the purchase order.

All tests are witnessed by Astronautics inspection and the test data reports are certified by the source inspector.

Wherever possible duplication between supplier acceptance testing an receiving inspection testing is minimized, again consistent with complexity, critical nature and special test requirements.

In the area of end items, these are limited primarily to subcontracted Aerospace ground requirements or ground support equipment and they are again covered by Astronautics design drawings and book specifications which again outline test parameters.

Normally these items are tested, final accepted at the suppliers facility to pre-approved test procedures and direct shipped to the launch

facility or launch site, after, of course, our final acceptance and government inspection of final inspection.

I thought I might mention the specially selected parts that were part of the pilot safety program.

Special supplier and receiving inspection tests were very limited. Generally standard receiving inspection procedures were used, critical components were selected by mutual agreement between SSD, Aerospace, and Astronautics, and the parts list was controlled through the issuance and control of a quality control departmental instruction.

Special selection criteria was not based on special testing as much as it was on special controls.

There were five Mercury-Atlas components selected and restricted to a specific procurement source but these had no other special selection criteria. There were five of those.

The general selection criteria used was again standard tests and acceptance standards. No transient malfunctions associated with any non-repetitive failure, no excessive operating time, no repair or refurbishment not specifically approved by a special Mercury-approved material review board.

The special selection criteria varied with the type or nature of the component.

One common special criteria was selection from common bands or tolerances -- not common -- control bands or tolerances nearest to the nominal value.

Again the additional controls for Mercury-selected components were close accounting of operating time, accurate detailed test data and records, test records, special storage and handling, complete log records of history of events and repair or refurbishment allowed only with approval of the Mercury materials review board.

Parts so selected were identified with the Mercury decal and they were special-handled in a special stockroom and controlled throughout the process from receiving through flight.

This ends my remarks.

Thank you.

I will be glad to answer any specific questions.

MR. PRESTON:

Any particular questions on this subject?

All right.

MR. BAZIK:

Tom Bazik.

With regard to 100 per cent inspection, I wonder if you can elaborate on the spot check of parameters?

MR. MEDLOCK:

Checked to the requirements of the test procedures for that specific part.

This again varies, as I pointed out, with the individual part. Generally, though, it is selected, those parameters that we feel were critical and designated to be tested. They didn't cover the entire range function of the part.

MR. WILSON:

Vincent Wilson, Langley.

Is this practice extended also to your other space boosters?

MR. MEDLOCK:

Yes, it is.

MR. WILSON:

Could I ask one other question, if I may?

MR. MEDLOCK:

It is extended to all electronic piece parts and functional piece parts, yes, sir.

MR. WILSON:

One other question. This selection of components getting a nominal rather than some other part of the acceptable band, now, insofar as achieving essentially perfect flights that the Mercury has flown, I would like to hear your comments on the selection of -- at least it is down the middle, so to speak, as it affects reliability?

MR. PRESTON:

Did everybody in the room hear that question? I can repeat it.

MR. WILSON:

I might state it a little better.

MR. PRESTON:

Essentially he is asking why did we select the norm instead of the outstanding in parts.

MR. WILSON:

What I want to know is this: I think I know why you did it, but I want to know what his comment is to the effect on reliability that you accepted any part that came within your normal tolerances.

MR. MEDLOCK:

I can't answer the question. I don't think I would even attempt to answer. But I think we probably have enough help that we can.

MR. PRESTON:

Hypothetically it shouldn't have any effect because that is why you set those tolerances.

MR. HEAGY:

I might take a flyer at it.

The tolerances that we use for the lower tier of checkouts are set up on a RFF- type basis such that we don't unnecessarily throw things away, the fact that we have this sequential testing and get a chance to look at the system tolerances with these off nominal components tends to equalize and get more toward the standard distribution that we have based our tolerance structure upon. But as to whether the reliability is affected by being more on nominal as opposed to being on the edge, I don't know that I can predict.

They are set up with the idea that if it is within that tolerance, it will work. Whether that has a relationship to the inherent reliability of the part itself, I don't know. But we do get a check of that component when it is hooked up to its subsystem and combined systems test and so forth to make sure that the total system is operating properly and as long as it is within those tolerances, we feel it is satisfactory for flight.

MR. PRESTON:

I think part of the trouble stems from the fact that it depends on whether you are in a large scale operation or a bits and pieces research and development operation as to how much attention you can pay to the particular out of tolerance.

Now, I know in the case of the spacecraft, we flew many things that were out of tolerance, but before we did, we had a little analysis of our own of what is the significance of this thing malfunctioning and we went

through a little plot process of is this a flight safety item or mission safety item or just in the nuisance factor? Usually when it got down to a flight safety or pilot safety problem, you changed it, or if it was just something that might be of benefit to have it work, you might not change it.

But in those cases you have to have an intimate familiarity with the equipment which you often do not have in a big organization to allow this analysis.

MR. WILSON:

Let me ask just one more question. I don't want to beat this one thing to death, but I would like to pursue it a little further.

As a consequence of the very good experience you had with the Mercury boosters, have you gone back and re-examined your tolerances on some of these items in the light of your experience with the ones of the components that are on the nominal?

MR. HEAGY:

We have taken any experience we get, whether from another program, and evaluated it against Mercury and vice versa. We have not gone to narrowing tolerances just for the sake of narrowing them on the program.

MR. PRESTON:

It is a very dangerous thing to do because it is expensive. You throw a lot of parts away.

MR. WAMBOLT:

I'd like to clear up a misconception on this subject of the special components established for critical components. It is not the criteria that said part had to be nominal. This is actually a rule or policy adapted to all parts to make it easier to predict how a particular system would operate.

Now, our five basic criteria for determining critical components were based on selection of components in a particular system, as an example, program import system, Mercury standard, Mercury mission only, and it couldn't be used anywhere else. So it became a critical control component. Other criteria were unsatisfactory operating history.

It that part had a bad operating history that was not at that point explained, we give it critical attention for that period of time until it was cleaned out.

Another criteria was vendor restriction as Dan pointed out and critical application and in the case of critical application we considered the abort sensitive unique and if they failed, we had nothing but a problem.

The last one was operating life. But really the only components that were selected on the basis of nominal performance were the engines, and the engines were selected this way mainly because there was not enough time or data to explain why a particular engine was almost the limit of the specifications, either above or below. So we didn't know enough about that particular engine. We could have picked high engines, but didn't know why they were high, we didn't know, so we decided to play it safe and pick the ones in the middle.

MR. PRESTON:

I understand that was an agonizing decision to make.

MR. WILSON:

I think you see why I asked the question because it agonizes some of us unmanned program people. We do not get the same treatment should we ask for it.

MR. PRESTON:

All right, let's come back to that a little later, will you please?

MR. WILSON:

Yes.

MR. PRESTON:

The next panel member is Dick Keehn with GD/A. He is going to discuss the factory vehicle acceptance tests that were run here.

Dick was the assistant program director for Mercury and Centaur Space Vehicles and been there since 1961 and before that was responsible for the checkout of all Atlas and the Atlas program and he was in this role since 1954.

Dick, would you go ahead?

MR. KEEHN:

Yes, thank you, Merritt.

As an introduction to factory acceptance testing, the goal of factory acceptance testing is to be able to deliver to the site a vehicle that is as nearly ready to fly as is possible to make it in a factory, recognizing that there are some limitations that you have regarding the nature of tests that can be performed in a factory, particularly on this type of a vehicle. You are limited in that you cannot exceed certain pressures safely within the confines of a building heavily populated with people. You can't, of course, write off engines or handle toxic materials and gyro techniques and many such limitations.

However, after having quite a lot of experience in working up to the Mercury program through the Atlas A, B, C and D series of missiles, it was possible through this experience to come up with a fairly comprehensive test plan that would provide objective tests of each system individually as well as a combined simulated flight type of test that would answer most of the questions, if not all, that are normally brought up concerning the integrity of a booster.

The booster itself, of course, as has been mentioned, was developed as a weapon system, was basically the D series Atlas Missile. There were some modifications to it necessary to make it peculiar to the Mercury program, but these were kept to a minimum and restricted basically to the addition of the abort sensing and implementation system, some minor modifications to the rain safety system, some modifications

to the propulsion system, they deleted the vernier solo portion of the operation and also the addition of a peculiar telemetry system which is not unusual since each program has specific requirements in this area.

The test equipment that was required was identical in most respects to that used on the weapon system.

Here again there were peculiar changes and modifications incorporated but these were kept to a minimum.

The procedures that you have heard quite a bit mentioned of today, this morning and this afternoon, were very carefully controlled and very carefully analyzed for completeness.

Mr. Wambolt mentioned that there were over 50 changes to a particular procedure, a flight control procedure. This represents the care, I believe, that was taken in the preparation of these procedures.

Most of these changes were of a very minor nature, but one of the primary purposes of having accurate procedures was to provide a permanent record which could be gone back over by virtually everybody in order to evaluate the tests that were performed on a particular system and review any subsequent data that may have been developed from whatever source and be able to evaluate the system on that basis and come up with an evaluation of deterioration if it existed.

One of the very important parts of the program in the factory was the selection of personnel. This was done very carefully and in general those people who had the most extensive experience on the Atlas Program, along with proven ability, were chosen for the acceptance teams.

These people were not always the most senior people. Quite often they were not, but they were in the estimation of management the best qualified from an experience-ability-temperament standpoint to fulfill these positions.

After the crews were identified, they were maintained intact as nearly as possible throughout the life of the program. There was very little transferring of these people about into other checkout areas.

I mentioned this morning in the session for those of you who may not have attended the session on human factors that a great deal was done throughout the plant toward motivation, the motivating of these employees to do a good job. We set up competitive goals so to speak for these people to work to. We gave them special recognition and so forth.

Now, the basic formula for testing these launch vehicles in the factory consisted of two phases. The first phase was the testing of each individual system individually and separately without any interface with other systems. In this fashion each system can be exercised through its entire band of operation and detailed records taken and evaluated to be certain that it is functioning precisely as it is supposed to without fear of any interference from other systems.

After these tests have been completed satisfactorily, it is planned to run what is known as a composite test which, as the work implies, is a test utilizing all of the various systems simultaneously. This test has come to be known as the final acceptance test as well and consists of all systems functioning in the manner that they would be expected to function during flight and programmed automatically through tape and control switching so that they would be exercised through all the extremes that they would be expected to operate under during a normal flight.

Naturally a lot of records are being taken during this time and afterwards these records are gone over in extreme detail by the quality control people from Astronautics, the Air Force plant representative and his engineering staff, the Space Systems Division of the Air Force, and their Aerospace representatives would also review this data in detail.

When all of this data was considered acceptable, then the missile itself was then considered from an overall standpoint as to whether it could be shipped to the site.

Now, during this over-all review -- and this review is participated in by the same functions of quality control and Air Force -- a review was made not only of the tests that were most recently performed, but all of the missile records would be reviewed. They would go back and pick out the individual acceptance records on each and every critical selected component and go back over these to determine at one final time that these parts were, in fact, up to the standards that we had established for

Mercury. They would review all of the failure history, all of the rejections that had been initiated on the missile would be reviewed and a corrective action noted. They would also review the physical status of the missile keeping in mind that as all this testing is going on, there is a physical part of this business, too. The thing has to be put in certain shape, it has to go through certain inspections. The nature of the inspection squawks and even the number of squawks were noted and commented upon and, as I mentioned, failure analysis played a big part in the Mercury program.

We had established as a ground rule that no missile would be delivered from the factory unless or until all failure analysis reports were complete.

In many cases this did not mean the final report, necessarily, because this takes two or three weeks sometimes just to get through the domestic problems of printing, but we would have an answer. The actual analysis would have been complete and available for the review team to evaluate.

Colonel Richardson is going to have more to say on failure analysis, so I won't say anything more about that now.

There were some exceptions in the way the missile was tested and these exceptions were handled deliberately and very carefully. An example is the treatment of the guidance system.

The guidance system was manufactured by General Electric and for the Mercury program they were asked to provide the Air Force with fifteen sets of guidance systems that had been built on a special production line using the special care that they had been impressed with as being required for Mercury.

Now, these units were treated specially, once they were received at Astronautics, also. We would use these systems only for the final test. We did not leave them on the missile to accumulate operating time while other systems were being operated. For this purpose we would use what I call a leapfrog system, which was simply another guidance system that was not of Mercury quality, but could be installed on the missile and operated and perform the same as the flight quality item without accumulating a lot of time on the flight system unnecessarily.

I mention this only because it represents an exception or apparent exception to what we have mentioned.

In conclusion the acceptance, the factory acceptance of the booster was accomplished through the accurate control of all systems and composite tests with an emphasis on personnel selection and personnel motivation.

A great deal of the credit must be given to the system of checks and balances that have been mentioned earlier, that is, the Air Force watching us and Aerospace helping the Air Force watch us. This can take on a bad connotation if you lose sight of that magic word of "teamwork."

This watching of everybody was not really an undesirable thing, it was not a unilateral thing. It was treated as a team with the Air Force, Aerospace and GD personnel working together.

The net result was that we were able to deliver to Tom here a booster to the site that was as nearly ready to fly as possible.

As a matter of fact, the Mercury program achieved what no other space program at Astronautics has been able to achieve and that is that we were able to deliver boosters to the Air Force without any deviations to our contract attached to the final acceptance paper. We were the first program to ever do this and it was remarked upon by many people that it was a major milestone and could be attributed basically to the efforts of the team and the firm requirements for having no shortages, no unaccomplished time in a detailed test program and live up to the program.

Thank you.

MR. PRESTON:

This gentleman over here (indicating).

MR. HUGHES:

Bob Hughes.

I would like to know if your final acceptance test included a check of your propulsion system?

MR. KEEHN:

During the final acceptance test the propulsion system is tested for valve operation and sequencing only. There are no propellants aboard and the pumps aren't turned, of course, and things of this sort. So the only test was a valve operation and sequencing.

MR. HUGHES:

Would you simulate a flow meter, for example?

MR. KEEHN:

No.

There were other tests, however, that could simulate all of the instrumentation transducers that could be simulated reasonably. If a flow meter could be exercised with a flow of gas, for instance, at a low rate, this would be done.

The temperature transducers were exercised if the ranges were reasonable.

We would not make any attempt to exercise cryogenic transducers, for instance.

MR. HUGHES:

May I assume correctly that the first time the propulsion system was operated and on the missile, was that at the Cape?

MR. KEEHN:

Yes, that is the first real exercise of it, yes.

VOICE:

You mentioned the tag value.

MR. KEEHN:

That's right, the engine had been hot fired before we ever got it, of course.

MR. HEAGY:

You might mention, Dick, that the engine is electrically tested and functionally tested here. The only thing that isn't tested is the operation of it or the filling of it with propellants of some type.

VOICE:

Is the engine accepted by the customer before you get it?

MR. KEEHN:

Yes, the engine was delivered to us as a GFPI item.

MR. PRESTON:

The next panel member is Tom O'Malley. He is presently chief test conductor at AMR for Convair. He was the test conductor for all the Mercury shots up through John Glenn's flight and then he was promoted to chief test conductor.

Tom will talk to you about the AMR testing from receiving at AMR through the countdown to launch.

MR. O'MALLEY:

Thank you.

I would like to refer you back, if you can remember, this morning we were in the other room where they were explaining how we had this contract set up for GD/A to work for SSD, NASA supplying funding to SSD.

SSD was responsible for the checkout and launch of the vehicle and they stressed this responsibility to the 6555th AMR.

They, in turn, set up a management tool to perform this, by performing what is known as a flight test working group.

This flight test working group is composed of senior members of contractors and associate contractors at the Cape. Some of them are GE, Burroughs, Rocketdyne and ourselves. The responsibility of this group is to take care of the operational problems that occur at AMR.

The first thing we do before we get the missile is to get together and form what is known as a flight test directive, which includes all the testing that each contractor will do on the missile or at his lab to assure that the vehicle will be properly checked out prior to launch.

Then GD/A assembles this into a document and it is approved by each contractor. It is known as the flight testing directive or, as we refer to it, the "Holy Bible."

Also another responsibility of this group is to come up with an overall schedule of milestones of the important testings such as the dual propellant testing, the booster fact test, simulated flight tests and the final countdown.

We, GD/A, perform our systems checkout from procedures known as test procedures and they are released engineering documents. When we perform a test, the system engineer is in charge of running the test. The technicians perform the work for him and inspection verifies that the function or step has been performed.

The system engineer signs off the procedure as its being satisfactorily completed.

I would like to stress this, that we often hear people say, "Well, inspection bought off the procedure." Inspection verifies that the procedure was completed. It is the engineer who is buying the procedure off.

Before he can buy it off, though, there are four steps we must go through.

The data collected from this procedure must go through our engineering data group and there they compare the data from the test with the parameter document, which Mr. Heagy talked about. When engineering data gives an O.K., we can come back and sign off the procedure before a Mercury flight Tiger Team must review it, and this Tiger Team is a group of engineers, design-type engineers, from SSD who came to AMR to review the procedures, to see that everything is satisfactory from their design viewpoint.

Further, we have a flight safety review team composed of Aerospace, AFQC, 6555th, and our own system engineers. These fellows, too, sign off on the procedure.

The missile arrives on a C-133 and it is delivered to one of our hangar areas where we install the loose hardware. They run the engines. The launch vehicle is taken to the complex and erected.

At the complex we perform all the missile system testing. We do each system individually. Like on the propulsion system, we perform an electric and functional test. We run a complete autopilot system, guidance, ASIS, range safety command and telemetry. The canisters from some of our systems, such as autopilot and guidance, are sent to our laboratories at the base for confidence checks to be sure that they are still in the same condition they were when they left San Diego.

When we have completely checked out a system, all the systems, we get up to what is known as the propellant tank and the booster fact test.

Propellant test is the climax of all mechanical testing.

A booster fact test is a climax of all electrical testing.

On the fact test we inject the umbilicals and simulate a flight of the bird electrically.

On our propellant tanking test, we put a proper amount of fuel aboard and simulate a launch countdown condition.

When we have satisfactorily completed these, we are ready for the mate of the capsule. When the capsule is mated, we perform integrated

missile testing with the capsule people. These consist of joint fact, electrical interface, abort check, flight configuration of abort checks, and simulated flight.

At the conclusion of these we are ready for a launch countdown. Prior to the countdown we run a series of readiness checks on each system. Where possible we run an end-to-end check. When these are completed, we have what is known as a status review of the flight testing working group.

There each contractor is required to report the status of his system. If everything is satisfactory, we are ready for a launch countdown. The countdown is a document which takes all systems into consideration and where possible, it, too, gives an end-to-end test on the system.

The length of time for the Mercury countdown is usually 360, 400 minutes, in around there. It varies from flight to flight.

The readiness checks that I spoke of are completed two to three days before flight and before somebody asks me the question, Pan American did check out the diesels prior to the countdown, but unfortunately on the countdown day it would not start. Since then the procedure has been changed and it will be checked out before we pick up the count.

MR. PRESTON:

They almost wore it out the next time, didn't they?

MR. O'MALLEY:

Yes.

Prior to going into a count, we assemble all engineers in one room that are going to participate in this. This includes NASA people as well as ourselves, and we give our GD/A engineers a copy of what are known as red line values and we give the instructions to the NASA people, McDonnell people and GD/A people who are participating in the count, that if in their opinion at any time they see something wrong, to call it out. If it is in the final minutes, after the minus 18 seconds, they are to call "cutoff," and we instruct every one of them that "If in doubt, call it.

If wrong, you will not be criticized." This is one thing that I would like to emphasize again.

You keep hearing it over and over again about team spirit. But team spirit on that Mercury crew down there was terrific.

I would like to make a few recommendations that we have learned and have passed this on to our other missiles that we are checking out at AMR and that is documentation. Our procedures, as I said before, are engineering release documents. Any troubleshooting that is performed at AMR on our boosters is done by procedures with what we call a procedure history sheet attached to it and the purpose of this sheet is to document every step taken during troubleshooting. We found it very beneficial that when you run into a problem and you document what you did, it is much easier to analyze it later.

That concludes my talk.

MR. PRESTON:

Any specific questions on this particular item?

(No response.)

MR. PRESTON:

Our next panel member is Bill Gilliland. He has been with General Dynamics for about twenty-five years in the quality control and quality assurance area. He joined the Astronautics Division in 1961 as manager of quality assurance and is responsible for process control, quality engineering, data center and corrective action and reliability failure analysis.

He is going to speak to you on failure analysis and data control.

Bill?

MR. GILLILAND:

Thank you.

As for the three areas he spoke of, I thought I might give a few comments regarding the putting together of this organization during the development of the Mercury program.

At the outset of the program, these functions were partially duplicated by different departments and actually were under the control of various departments. As a result of putting these three organizations together we feel we have a more closely-knit organization and, therefore, a better result as a result of this control.

I thought I might give a few words regarding some of the important steps actually contributing to the Mercury program. They were actually established by quality control.

Quality assurance provisions in the engineering detail specifications, that is procurement specifications, a spec control drawing was actually provided by the quality assurance group. It identified and established the individual acceptance test and the production evaluation tests which were in effect on the Mercury program.

From this requirement, the quality assurance group then developed equipment operating procedures which were to be used in receiving inspection and for subassemblies throughout the manufacturing and testing cycle.

To give a few more comments regarding the production evaluation testing, the quality assurance group identifies the sampling frequency. They approve the test procedures and witness the test operation with the follow-through of corrective action.

We had approximately 600 of these items involved in the PET program and sometimes it was the "pest" program. Some of the routine things that were normally conducted by this operation which we felt played an important part in the test program were the nondestructive test activities, including X-ray, the production vibration testing, contamination control

and a routine physical-chemical analysis of incoming materials and processes during the manufacturing cycle.

A few words about the data center and the corrective action area.

The area of primary concern when we speak of data center, involves failure data. All hardware failures on the Mercury program were evaluated at the point of rejection by quality engineers and reliability engineers assigned to the areas. We had engineering people with different specialities assigned to these teams. They collect, collate and analyze data and record operating time. They provide routine and special daily reports. They identify critical history parts for engineering for appropriate action.

In the failure analysis and reliability parts laboratory area the failure analysis group for all programs runs a physical analysis of all critical and major hardware failures. It is associated with production components for both airborne and ground support equipment. This capability is supported by the GD/A laboratory and also the manufacturing departments.

In the parts laboratory we accomplished qualification and parts evaluation for engineering.

The foregoing is a brief sketch of our normal tests. Some of the areas have an increased emphasis and I think the program today has been basically one of showing increased emphasis in testing Mercury's systems and components.

We emphasize strict control over contamination for components, propellants, and hydraulic and pneumatic systems.

Now this doesn't mean that we don't exercise strict control on the others, it means in some cases you duplicate tests making absolutely sure that the results are correct.

Nondestructive testing was used to a greater degree, the seam conductors were checked for contamination and configuration and we exercised surveillance over the production vibration control test program. One of the questions brought up by Mr. Evans of Martin, regarding wearout in this particular area, was one of our concerns in that in any one

component the modules that went into the canisters did not exceed the maximum or desirable amount of time of vibration. It gets to be a point of wearout. Therefore, that was a particular area of concern.

We run special audits on tests and test data of components. We gave special emphasis to the individual acceptance tests as well as the component tests in the control of the production planning for the requirement of these tests.

In the data center and corrective action area we put special emphasis on the evaluation of failures that occurred on other programs for their influence on the Mercury program.

All corrective actions that were evaluated or required were completely evaluated at the point insofar as practical.

If the problem could not be isolated, either the component and/or a system that was involved was withheld from production until it could be isolated.

The failure analysis group often came into play at this point in the problem area. They would give the go-ahead when they had isolated the problem area and that part or component removed from the system and then they would conduct their cause-of-failure evaluation of that particular element in the laboratories or wherever necessary.

One of the things that they did on the Mercury program was to maintain a high priority level of effort and attention to the problems developing along the production end test lines. Often this meant that engineers assigned to the test would work practically around the clock in order to give clearance to again put the production line on an even flow.

All failures of ground support for airborne equipment at both the plant and test sites were handled in the same manner.

The failure analysis engineers participated in the various evaluations that were handled by design test engineers, special Tiger or working teams assigned to the Mercury program.

I will turn the mike back to you, Mr. Preston.

MR. PRESTON:

All right, thank you.

Any specific questions on this?

MR. GRADY:

Yes. Bill Grady, Aerojet.

Did your failure analysis include failures that occurred during the research and development program?

MR. GILLILAND:

We did not have it in that degree and some special items were sent to the laboratory, and some of our future programs will.

Do you know of any, Hal?

Hal Story, he runs the group.

MR. STORY:

We assisted engineering design in a few cases. In future programs we will be assisting as a general rule.

MR. GILLILAND:

Does that answer your question?

MR. GRADY:

Yes.

MR. HERMIES:

Carl Hermies, Lockheed, Sunnyvale.

Did I understand you to say that you were running X-ray tests on semiconductors?

MR. GILLILAND:

We did on all transistors for the program, some rectifiers and some other isolated cases of diodes.

MR. HERMIES:

One hundred per cent?

MR. GILLILAND:

On transistors, yes.

MR. GRADY:

Did you find anything?

MR. GILLILAND:

I think Lockheed, Sunnyvale knows we found some things. Yes, we had a rejection rate, it varied with different types and manufacturers.

We still reject on the basis of one to three per cent of incoming items if they have not been subjected to X-ray by the supplier.

MR. PRESTON:

All right, let's move on to the next panel member, who is Lt. Col. Pete Richardson from the Air Force. He is assigned to the Mercury program and is a factory representative to the program office.

He will talk about Air Force test control.

Go ahead, Pete.

LT. COL. RICHARDSON:

Everything that I was going to say has been said.

I would like to summarize and stress the value of the failure analysis program, which is tuned to the program itself in terms of time.

Failures have valuable data, providing they are analyzed down to the absolute source of data and corrective action taken. The corrective action should be tuned to milestones that you see in the movement of a booster from assembly through acceptance and out to the Cape.

No booster was accepted for entry into composite tests if there were any open failure analyses which could possibly affect its configuration after corrective action was taken. There was no booster accepted at the buy-off point with any failure analysis open, which again could have affected the configuration or the reliability, and again, two weeks prior to launch all failure analyses which were then open were then either closed out or adjudicated as not affecting the mission.

I think really if you look at the history of the booster it tends to show that the reliability of the booster has significantly advanced and I think that the failure analysis program played a large part, although not the total part, in this increase in reliability.

Back to you, Mr. Chairman.

MR. PRESTON:

All right, we can open it for general discussion.

LT. COL. RICHARDSON:

Richardson, Hughes Aircraft.

With the first booster that you delivered complete, do you find now that you have accumulated all your test data as factory test data that you have a significantly improved booster on the Mercury program relative to failure, reduced manufacturing cycle, some of these other measurable

parameters on factory performance? Do you think you have improved your weapon or booster with all that handling?

MR. PRESTON:

Dick?

MR. KEEHN:

Yes, I believe there has been a significant improvement, but recognizing first of all that the booster was basically a well-designed booster to begin with or you could never have attained the degree of reliability that it did attain. And if you accept that as a ground rule, then how good a booster it is from that point on is relative and directly related to how well you test it, how well you perform your test in evaluating the results of this test. And I think that during the course of the Mercury program we gained an awful lot of experience and we did a lot more detailed searching of what previously had been considered insignificant variations to the point that we did institute minor changes in many cases which have been reflected throughout the entire Atlas program. So I think without question the entire Atlas booster has improved in reliability, basic reliability, as a result of the Mercury program.

MR. PRESTON:

All right.

MAJOR BACKES:

Major Backes from the Atlas Weapon Systems Program Office. I have been with them for about four and a half years and associated with testing.

I am interested in the statement that Mr. Keehn made, that all Mercury boosters were delivered complete without deviations.

We haven't reached this happy state with the Atlas. I realize that this is largely, perhaps, due to our higher pressure on schedules and perhaps some more changes than what Mercury made. But I am interested enough to ask this: What was the impact on your program in terms of scheduled slippage that had to be beaten because you chose this policy?

MR. KEEHN:

Well, this was not without impact by any means. If you recall from Mr. Dempsey's talk this morning, the eternal triangle bit, on the Mercury program we were primarily concerned about reliability and as for schedule -- I don't mean to say that we didn't regard schedule important, and I didn't mean to imply that all Mercury boosters were delivered without deviation. It was just the last one or two that came up to that standard and if there had been exceptions to this that were of a minor nature, we undoubtedly would have made them rather than sacrifice additional schedules, but there were many instances where a schedule was not considered at all.

As a matter of fact, the very last booster, we ran into a problem the day that we expected the booster to be accepted and during the acceptance meeting this was brought out and we decided to hold that booster there for an additional six weeks, which was the impact of that particular item, but a quality item, and we felt could best be handled by leaving it in the factory.

MAJOR BACKES:

Then the original policy is no deviations?

MR. PRESTON:

It takes judgment in any case. Any policy takes judgment to exercise.

MR. KEEHN:

An absolute policy of that type would not be practical, I don't think.

VOICE:

I have two questions that I would like to pose to the panel, but I think a little elaboration would be beneficial.

One is a comment that Mr. O'Malley made that we take the booster to AMR. Due to the transportation in the aircraft, after we go through receiving inspection and erect the vehicle, frequently we take the canisters

off and run them over to the laboratory for a component-type testing. I think since the Mercury program -- I do not know how much of this was done on the last few vehicles for Mercury -- but I think we can all agree that it gets to be a controversial subject on how much of this component testing you do.

In other words, you do a significant amount of testing and try to deliver the most complete and flawless vehicle possible in the factory. You run it to AMR. You have all sort of management control as far as getting it on the aircraft and making sure that nothing gets rattled and then you get there and you take the canisters off and run them all over to the laboratory. So there is, I think, a line here for discussion of how far you go down this road of going into the laboratory in the field versus retaining the integrity of the systems test you conducted in the factory.

In other words, going into systems tests, not validating the systems test you conducted in the factory. Then if you run into a problem at AMR, you take the proper action. So I would like the panel to kick that around if you will.

MR. PRESTON:

Tom, will you start?

MR. O'MALLEY:

I will start by saying we take the canisters off the bird when it comes to AMR and bring it over to the gyro lab and run complex tests on it and to be real truthful with ourselves, say that experience has indicated that we will continue to do it until such time as the data and the facts indicate that there is no longer a need for it.

But I recommend it firmly for a Mercury program or any space shot that we conduct and continue to conduct these tests.

We are looking for a reliability of 100 per cent when we fire a bird, and the only way you can get it or try to even approach it is by testing it to a point where there is no doubt that it will perform properly.

MR. PRESTON:

I would like to add to that by saying that it is my firm opinion that reliability is achieved through test and retest, and only through this do you obtain a confidence that the thing will continue to function after you let it fire, and I think that the reason that we at AMR take things out of the bird is because we can do the job more efficiently and better if we take it out than if we leave it in. So it becomes a problem of how best to do the job. We don't do it just for the fun of taking it apart.

I think there is a misconception of how we tear the vehicles apart when we go to the Cape.

I don't think that is true at all. The general policy is to not take it apart unless you can do a better job if you do. This has been a misconception for quite a long time, that is not the case.

Anybody else want to add anything to this?

MR. KEEHN:

I'd like to add one comment and that is that one of the criteria for reliability on any space booster mission has to be more than the evaluation of a single set of data, but the more data you can obtain for the purpose of looking for deterioration is what you have to have.

Now, in this case you have to recall that this launch vehicle has been subjected to a pretty strenuous environment from the time it left our plant until the time it arrived at AMR.

Years ago when we sent it over by the highway, it took eleven days of bouncing over the highway to get there. Now we send them by aircraft, which some say shake it up even worse. But nonetheless it has been subjected to a rather severe environment and we always felt that the data that we received from the laboratory tests down there have been very meaningful and pointing up deterioration in systems.

MR. PRESTON:

I think that it is inconsequential in my mind whether the trip did it any damage or not because even after we get it to the Cape we test the same system over and over. It is only through this exposure to failure you get something to fail, and you know that it will work if it hasn't failed, and this worry of overtesting is something that I think there is too much emphasis placed on because reliability only comes about by familiarity and you only become familiar with something by testing it.

Before there is another question, does anybody else want to add anything?

MR. O' MALLEY:

I want to add one other thing to it, too.

On our autopilot system for flight control systems we go a little further than what Mr. Preston is saying, we test three sections out at the lab and on the bird we test out two complete sets. We only fly one, but we check another one out completely and have it ready in case we need it. As we change a component, we will change a system.

VOICE:

And there are some things that you cannot run even on an autopilot, like rate gyros, you cannot run on a missile pad?

MR. O'MALLEY:

That's correct.

VOICE:

You can only do this in a laboratory, so part of that test that you call a system test or composite test, you can only do in a laboratory and handle it until it is installed.

MR. PRESTON:

When you say "run," you mean completely functioning?

VOICE:

Yes.

MR. PRESTON:

This gentlemen over here?

VOICE:

In the event of a failure on a system that is undergoing canister testing in a lab, what is the procedure for that kind of a test?

MR. O'MALLEY:

All canisters are shipped back to the factory; except telemetry, we open them.

MR. PRESTON:

Over here?

MR. POWELL:

Bruce Powell, Boeing-Saturn.

My question, which I will eventually get to, is directed to Mr. O'Malley and Mr. Gilliland and concerns data collection.

It has been my personal opinion, formed from observation at AMR, that on the Saturn program, that data are not being adhered to, and yet I get the impression today that the Mercury program has had a very successful and complete data program. My question is: was the data program written by the contractor or by NASA people?

MR. PRESTON:

Bill, do you want to answer that?

MR. GILLILAND:

Well, the data that I spoke of was failure data. This primarily involved the rejection histories of the parts and we started it at the receiving point and followed through with the data and then we collated and we have a reference system on about 3,000 parts wherein we maintain files for those individual parts, and you can interpret the MPC document, I think, to require a tremendous amount of data which we do not provide under the current system, but from the receiving point on we do have a good history record of the rejections.

MR. PRESTON:

That is the MPC-200.

MR. GILLILAND:

The contractor does that.

MR. PRESTON:

The MPC-200 was not in effect at Mercury and did not affect Mercury, and I don't see that it has too much of a bearing.

As a general rule MPC-200 has been issued by General Headquarters as a general guideline for them to interpret for their particular program so it might be slightly different from one program to the next.

VOICE:

I would like to ask the entire panel, in particular Mr. Gilliland and his combined departments, and Mr. O'Malley and his AMR testing, and Colonel Richardson about his control on entering composites and so on. My basic question is: Certainly GD/A has learned a great deal from the Mercury program. Mercury has a program that you can't get in unless you happened to be in it.

I am trying to get the entire panel to present what I feel certainly has happened to benefit all space boosters on what has been learned on Mercury.

MR. O'MALLEY:

I will take a crack at it.

As far as space shots flown at AMR, they are handled the same way with the Mercury program, except contract does not call for Aerospace participation.

Procedures are identical where they can be, and the method that we check out is identical.

The format that we go through, the people that are connected with it, in a lot of cases, are the same people. Talking about data review, the same people are reviewing the data. The only difference in the Mercury or Agena shot or Fire shot or 1013 is the contractual requirements such as Aerospace participation.

MR. PRESTON:

Tom speaks with authority since he bosses them all.

Bill, have you anything to add?

MR. GILLILAND:

I was wondering, insofar as the failure analysis is concerned, which, as Colonel Richardson indicates, plays an important part in getting off to the right start, we fundamentally do the same thing on the other programs, but we often proceed further down the line before we get all the results from the failure analysis. In other words, we take a little bit more risk involving some of the other programs, but in effect eventually end up with the same point.

MR. PRESTON:

I think the fact that the man is on board, though, stimulates you to do more and put up with more annoyance because some of these things get to be annoying, particularly at T-minus two days and a big flap comes up and you wish somebody didn't talk because all it is is more trouble. But the fact there is a man on board might, I think you might be a little more willing to forget it, I am not sure. I have always been on the man side.

MR. HEAGY:

I think when we started a lot of flaps because of the man being in there, being overconservative, there were unnecessary flaps to really go back and to have a chance to fly it in a previous configuration. We just went overboard in making sure that everything was satisfactory, to everybody's satisfaction.

MR. PRESTON:

But that is the only way you get this reliability that you achieve and strive for.

Now, you are saying that maybe it isn't really worth it?

MR. HEAGY:

I am saying that we had a pretty good reliability at the end of the Golden Ram program and a man was not involved in that. So it is possible that the same reliabilities can be achieved, but we went overboard, and I think rightfully so, to make sure that we did bring to proper focus anything that was questionable and then get everbody pacified.

VOICE:

Do unnecessary flaps generate any change in your final test procedure?

MR. HEAGY:

I don't think there is any substantial change in the scope of testing done on the Mercury than what was done on the regular program.

MR. O'MALLEY:

You say do we change our procedures because of the result of testing we do?

MR PRESTON:

Of the problems.

VOICE:

I am trying to find out if the program you started with, you were over-protective and you found that you generated a lot of extra work that you could relax, when you got downstairs -- let me try again.

Let's pretend that you had a test program, you had requirements; when you got down to missile 130, did you find out that some of the procedures you had on missile 10 were unnecessary?

MR. O'MALLEY:

I know of one that was unnecessary.

MR. PRESTON:

That would be, generally, the opposite way, wouldn't it, Tom?

MR. O'MALLEY:

If you start with 10-D and go forward, I'd say we added about 20 or 30.

MR. PRESTON:

I think there is a difference of 20 because the Atlas 10-D, I think we said this morning, had fired what, 75 for 10-D, something like this, you had

a big background. I know in the case of the spacecraft -- in fact, I made an analysis of the testing time spent at the Cape and you would think that there would be a learning curve. There was a learning curve but the learning curve was that we learned how to better check it out so it took longer because we did a lot more testing.

Any time you have any trouble on the ground in test or in flight on a test then you develop procedure to try to prevent that on the next one.

You have to continually review the procedures that you are using to make sure that you are not making superfluous tests. It is pretty difficult. Once you have done it one way and it is successful, you are sort of reticent to change.

I think in our case in the space capsule it grew a lot more. I'd say we doubled the number of tests between the first and the last test, whereas the Atlas didn't because they had a pretty well developed test program.

MR. WAMBOLT:

In the factory we generated a lot of problems because we were looking for anomalies, like I said in my talk, that we did have this concept of trend analysis coming to the fore. And as the missile itself got to the point of reliability, that we were having major problems with the subsystems, we began to look deeper in the subsystems to fine problems and -- true, we found a lot of false alarms, but what we ended up with at the end of the program was step-up in the amount of data recorded and the amount of information that was given in this paramter and the test itself. This began to take more time and we found ourselves arguing about details on Missile 130-D and 113-D which back around the days of 10-D would be unheard of. People tended to overlook them.

So we have the same emotional effort expended on the program but on details that are far below the kind of problems that we had when the program first started, but the amount of testing has increased.

MR. WITHEE:

Just one item I might throw in. There is a lot of concern and we have it, too, on the wearing out of parts by testing -- too much testing.

I want to bring out the unified test plan emphatically because it is very, very important that you have a unified test plan early in the game, and that all of those people who can demand tests and rightfully so, for example, the designer himself, the systems engineers on the project, the QC man, the inspector, the quality assurance and the reliability man reporting to the customer, and so forth, get their requirements in early. If these test requirements feed into the design groups and test planning groups, and we make all these tests, but in no place is there one responsible man who takes all these tests, puts them in one line, i.e., unifies them, and makes one plan, then we end up with maximum testing and maximum duplication. We had learned prior to the beginning of the Mercury program that unified test planning really reduced the amount of testing we did, not only fewer identical parts were used, fewer parts destroyed in testing, but testing manhours were reduced, and I think with real good unified test planning we find actually that all this testing you are talking about didn't amount to more than we had been doing prior to that time and resulted in a better job and more usable test data.

MR. PRESTON:

Anybody else?

O.K., another question?

MR. MAST:

Lary Mast, Rand.

Mr. Preston, could you give us a quick summary of the time relationship that you just mentioned? You mentioned that you did a survey on the test times at the Cape.

MR. PRESTON:

Oh, you mean how much did it increase?

Actually, the tendency was in the first four spacecraft for the time for checkout to increase and then from then on it stayed stable, but the time required to perform a given test went down and the total time remained

the same because we were running more tests. So we have sort of leveled off.

Now, part of this is due, I am sure, to the fact that we were allowed so much time and the heat started to come on our necks, you know, but I think very definitely in the initial phases of testing and the device you learned how to do it and, therefore, take longer, and I would say it was increasing about, between those first four, between 20 and 30 per cent, the time increased for testing.

MR. McCULPIN:

McCulpin of G. E.

I think I would like to take advantage of the panel, particularly the General Dynamics people, and say all today we have heard about all the things that you have done in Mercury and didn't do on others. But could you give us a brief outline of what you are doing in other programs like your Atlas programs as a result of the Mercury experience that you would not have done otherwise? For example, your indoctrination of training, motivation, along with a more extensive failure analysis and the likes of that. This is going to be the proof of the pudding. You might have been able to afford it on the Mercury, but to do it on the others is a business decision and we look for that, does it face up to a business sense?

MR. PRESTON:

Then you have to face up to that triangle that Dempsey was talking about.

Wally?

MR. WITHEE:

I'd say this: that I think it is natural that things we learned on Mercury were adapted to other projects. We have one set of test laboratories, as an example. Now, if you are going to have several programs within one set of test laboratories, then you would rather have them all the same, to save time, procedure duplication and other things. So to a great extent, where one function which serves all programs was affected, when

Mercury came along with something better, a better way of handling test parts or procedures or this unified test plan, for example, this improvement has tended to go into all projects served by that function. Design review and many other improvements became company policy. When we projected all our design areas, we had to have some type of systems integration across these projects, some way of making sure, over and beyond the normal communication between engineers in the projects, because actually they are in different buildings and remote from each other. So one man on one project wouldn't be making mistakes, and correcting them and the other projects be unaware of this information and possibly making similar mistakes. This System Integration group covers all specialties in design and works across all projects in this division. This group also influenced procedures, policies, and ways of doing things and so to a great extent we are, on all those programs that aren't too far along, using things we learned on Mercury. I won't say that everything good was found on Mercury. Sometimes another program recognized a fault and found a solution and this improvement was carried to the Mercury project.

MR. PRESTON:

I think this triangle has a lot to bear on this because maybe if you can even afford it, you shouldn't try for 100 per cent reliability, it might be cheaper to have 85 per cent in the long run, it might be cheaper to fly a different bird once in a while.

MR. McCULPIN:

In terms of the triangle, is the "R" important to be on top? Your programs in terms of Mercury?

MR. WITHEE:

In terms of most programs, yes, and new programs, yes.

MR. GILLILAND:

You mentioned failure analysis when you opened with your question. I believe maybe a point I can bring out here, about 10 months ago our failure analysis on production missiles was primarily in the composite

and test areas. As a result of our Mercury program, taking it back to the lowest level, we put it on a unified basis and now the missile programs are being treated exactly the same way in that respect, that every assembly is evaluated at the point of rejection for failure analysis.

MR. McCULPIN:

Do you find this cuts down on the number of failures you have in the final systems test?

MR. GILLILAND:

Well, I haven't correlated those statistics, but we know as a result, we will say, on 130-D, the Cooper vehicle, that is the number of tests that we have done.

MR. WILSON:

Wilson, NASA.

What number of failures have they had at the Cape?

LT. COL. RICHARDSON:

What is a better systems test than the flight itself?

MR. WITHEE:

I just mentioned to Merritt other examples that kept all programs similar: the increased activity we put in the standards parts list. Once you find that a certain part is to be handled a certain way through receiving inspection, etc., for one program, then that part, if it is used on any program, and it should be unless there's a reason it cannot be, because that is what makes a standard parts list, would be handled the same way; two - the Tiger Teams, -- The Tiger Teams were not primarily people from within that project. The top skill in the division and System Integration personnel that work across the division were on the Tiger Team.

You talk about costs, but I think you all realize that when you get into areas such as cost control that there are many influences to be considered, that unless you are careful and do standardize and use the best parts, even though it costs a few cents more, that you can really add on cost by controlling each item differently for each project. So to a large extent a great many of these findings from Mercury became standard on all projects.

MR. PRESTON:

You can take the specific example of the solder balls in the transistors. I don't think anybody will give you that trouble again.

Anybody want to continue this discussion or are you ready to continue with a new one?

MR. MILLER:

Fenton Miller, GD/A, and I represent another project.

I would like to make a direct contribution to this discussion and to this gentleman, and say that definitely the reliability of the Atlas weapons program has improved because of the Mercury program.

I can cite you an example and I think the Air Force people with us right now would bear me out on this, and solder balls are just the start of it, but numerous other things that have been fed down, and we have also fed into our program in those procedures and better inspection procedures and design.

MR. PRESTON:

I think it probably would be well to bear in mind that the whole space effort is sort of coming of age.

If you recall three or four years ago the success ratio was pretty low and yet I can point to the Thor Delta program, for example, which has an extremely high success ratio. Mercury is not alone in having an extremely good success ratio and I think this knowledge is being spread around the industry.

VOICE:

I think we can answer that another way.

NASA, Air Force and GD/A, by this workshop are attempting to make available to you all of the information and knowledge that we gained on this program.

Now, the decision on whether you adopt it on your programs, use your evaluation of the RCS triangle, just as any other program within GD/A must evaluate an RCS triangle. So it goes over and above what the other programs of GD/A benefitted from this.

You can take it a step higher and say will the experience we are trying to make available to you also be effective on your programs, and you are going to have to evaluate those the same as they do.

LT. COL. RICHARDSON:

One particular thing here, I think that it is only fair to say that the contract should require some of these things and if it is omitted from the contract, you are entering some negotiation stages an interpretation of what the contract does say.

VOICE: Do you have time for another one?

MR. PRESTON:

Yes.

VOICE:

I promised myself if I heard the triangle mentioned again I was going to ask this question.

I would like to ask the panel what they think of the triangle on a full CPIF contract. To me I think the triangle becomes meaningless.

MR. PRESTON:

That depends on who is exercising the shape of the triangle.

If the customer is exercising the shape of the triangle, I think that is a part of CPIF.

VOICE:

No incentive fee where incentive is based on performance and schedule and your cost?

VOICE:

If I may answer that, we currently have a CPIF contract for standard spares booster and this was handled in the very beginning by making a value analysis based on that triangle. And the two elements of cost and schedule were both recognized as elements of the incentive fee. That contract is tied to the performance or the reliability that generates a certain amount of the fee, at the same time the costs generate a certain cost of the fee. So two of the basic legs of the triangle are incorporated. In other words, it is not strictly a cost incentive contract. It is performance of reliability plus cost and one of the ways you can handle this with CPIF contracts is to tie both of them down so that you don't generate reliability by running costs up totally because you will reduce fee, by the same token you can't disregard reliability in order to keep the costs down to get it. You have to retain both and the formula you achieve for that is dependent on the individual programs.

So when you run this analysis and when you negotiate the contract, when you determine with your customer what you want, tie down both of them, and that I think, will then eliminate the problem.

VOICE:

Then the problem becomes a straight line, is that what you are saying?

VOICE:

No, not at all. It depends on the weight of factors you put in elements. If you put more on cost than elements, that shapes your curve.

MR. PRESTON:

I think the science of contracting and providing proper incentives is probably an exact a science as is space work. I thought for myself there ought to be a better way for the government to express its appreciation for what the contractor does for him, and I just feel lost. I don't think there is a good system. None of these contracts do what you want.

MR. HERMIES:

Hermies, from Lockheed, Sunnyvale.

Do you run a PET-type program on your small components in receiving inspection? Do you pull a sample out of each batch of resistors, etc., that come into receiving and run some sort of an environmental test on these prior to receiving a lot in production?

I gather you run some sort of test on a black box level.

MR. HEAGY:

It goes lower than that but I think Bill can answer that.

MR. GILLILAND:

If you would like me to, I have a list with me and I can go over quickly the type of parts that goes in this PET program. It goes down as far as a hose assembly which would be subjected to testing, cycles of pressure and temperatures, and so I will not go over that with you unless somebody is interested in the details.

MR. HOLTMAN:

Norm Holtman, Minneapolis-Honeywell.

Mr. Heagy, you mentioned on the electronic equipment you combined environments for certain tests like vibration and temperature. Did you get any feel on which environments involved were most useful for the specific program?

MR. HEAGY:

Generally the ones most likely to combine. We evaluated, for instance, whether it should be low temperature or high temperature, what the component would normally be in its use in environment, and use that coupled with vibration.

We have done combinations of temperature, vibration and acceleration testing. We have also combined things like altitude and with it whatever seemed to be the most appropriate simulation for that given part.

MR. PRESTON:

I think he was interested in if you could tell the difference between an isolated test and a combined test.

Is that what you wanted?

MR. HOLTMAN:

I was looking for perhaps a more generalized case for electronic components.

Did you find any specific combination of environments that was more useful than any other combinations?

MR. HEAGY:

I will have to start this one off and then ask for some help.

But generally, our electronic components are in a conditioned hot area such that there is not much variation in the temperature that is combined with the vibration. But I might ask Cy Campbell, who is in charge of that particular program, to see if there were any other detailed conclusions he came to.

MR. CAMPBELL:

Probably we noticed this in the case where we were exposed to greater extremes than we have in our hot area. One in particular was a transistor. We tested this a number of times with vibration and temperatures separately and never had a failure. But when we tested it with the high temperature, we expected it to be exposed to plus vibration, it failed. This was simply a case of the manufacturer using the wrong solder and, of course, by just applying these singly you can get the situation where the solder was shaken from the joint. So I think it is mainly where you have the more extreme, either high or low temperature. Also cases where altitude goes into this combination will expose it to other failures.

MR. PRESTON:

All right, any new subject here?

VOICE:

Did anyone on the panel or did any group in the Mercury program explore the advantages or disadvantages in connection with 100 per cent production acceptance testing at flight and environmental levels?

MR. HEAGY:

I might tackle it a little bit, having talked about this subject several times in general.

We have a production vibration program that I mentioned, which is our closest approximation to 100 per cent exposure to operating environment. The environment we selected for the production shake to determine workmanship and process errors turns out to be approximately the environment of the equipment in the pot. And so by accident it turns out to be a production acceptance test at whatever level is applicable to the piece of equipment.

There is certain other equipment that we do test 100 per cent as part of the individual acceptance test to something that approximates their environment.

I think of such things as regulators and boil-off valves and things of this type that are tested as part of their individual acceptance test with the operating fluid they will use in operation. But its performance is verified that way and that is probably more severe than the other environmental conditions we concede. But we fail to go into a 100 per cent flight condition on a component. We want to make sure we have not degraded the performance of the unit before we go into it. So we have a very energetic program set up now to evaluate the effects of a ground handling and launch duty cycle, if you would, on the component to see if it degrades its performance. If it does not, we have every intention to apply it initially on a sampling basis and possibly in some cases up to 100 per cent on the component in question, but only after we have made sure that it is not going to do us more harm than good.

MR. PRESTON:

One more short question.

LT. COL. RICHARDSON:

Richardson, Hughes.

I wonder if it would be possible for the members of the panel to include on the report that comes out a copy of some of the forms that you have used so that industry can see typical forms, failure forms, if you invented something new. When Mr. O'Malley talked about a form where he keeps a detailed sheet on troubleshooting, a few examples of this sort would help other industry members accept the techniques.

MR. PRESTON:

It is suggested that these be individual requests rather than a general inclusion in the reports. So we will direct your individual request to GD/A or some other segment of the organization like the Air Force, direct it to them.

I think this is all the time we have. In fact, they are waving their arms in the back of the room rather frantically for us to quit.

I appreciate everybody taking such an interest.

Thank you.

(Whereupon, the panel discussion was concluded at 3:45 o'clock p.m.)

Subject Summary of Panel Findings

Time 4:00 to 4:50 p.m.

Location Atlas Room

Mr. J. R. Dempsey, Astronautics, Coordinator
Col. R. Hoffman, USAF
Lt. Col. R. H. Brundin, USAF
Col. F. E. Brandeberry, USAF
Mr. J. Bailey, NASA
Col. M. K. Andressen, USAF
Mr. G. M. Preston, NASA

MR. DEMPSEY:

If everybody will take their seats we can get underway on the final, conclusion phase.

Now, in order to conclude today's activities, because we were divided into separate panel sessions in the morning and early afternoon, we have reassembled here with the panel chairmen and have asked each of them to summarize in about five minutes the discussions and conclusions that may have been reached or questions that were raised without conclusions in the six separate working panel sessions.

First, I would like to ask, Colonel Hoffman, who was Chairman of the Management Review Section.

COLONEL HOFFMAN:

I visited several of the sessions, and the thoughts that I learned in the Management Sessions were sort of borne out in the whole program. Key among those that we arrived at this morning was the emphasis on motivation.

Secondly, was the fact that we must have people-to-people communications, right down to the bottom of the organization, and all the way to the top.

Another item that became clear is that there seemed to be no real lines between NASA, Air Force and Contractors. The whole group worked together as a team.

The next item that we became clear on was the relationship of the reliability, cost, and schedule. The triangle and the emphasis in the space program on the reliability or dependability above all other criteria, whereas in the ballistic system, the schedule was the overriding, important item.

Then looking toward the future, we came up with three or four key points there. Our systems will continue to be more and more complex; there will be a decreasing availability of confidence flights. We can't

lean on a ballistic program to give us 90 or 100 flights to test out the things we wish to test.

One hundred percent reliability will continue to be very, very difficult to achieve.

Our problems or goals are to reduce and control the number of human errors. We will probably find no quick fixes and we must have controlled trouble shooting.

In the area of reliability there seem to be two schools of thought, one that the reliability organization should be separate from the rest of the organization, and then the other school of thought, the reliability was planned for incorporation into the existing organization.

Then during the question periods we came on three or four ideas. One was the importance of the failure analysis; another was the vital importance to have the procurement people indoctrinated as well on the reliability and the objectives of the program.

The third point that came up in the question period was the identification of the worker with the work, so that he could have the knowledge that he had achieved a piece of work and it was recognized up and down the line, not as a method of finding where the faults were, but as a method of rewarding the workers for good work.

Those are the chief items that I observed out of the management meeting.

MR. DEMPSEY:

The morning session on Human Factors was chaired by Colonel Brundin who was the Regional Mercury Program Director at SSD and now is assigned to the Air Force Academy.

Bob, could you summarize your session?

COLONEL BRUNDIN:

You recall the heavy emphasis which was placed on the human element by each of our speakers this morning. Our Human Factors Panel used that as the take-off point and devoted the majority of our discussion to the techniques employed in the Mercury program to motivate people to "do good work."

The real key to motivation appears to be, and this point was brought out by Colonel Hoffman a moment ago, the identification of the individual, and if not the individual, groups of individuals with the program and with the hardware.

To accomplish this job, essentially an educational campaign must be conducted by people who are themselves honestly and sincerely motivated. Astronautics used in-house literature, posters, films, seminars, and special problem groups to accomplish this, the latter more frequently than not used the local AFPR and NASA plant representatives, and when possible the astronauts themselves.

The very sincere interest and assistance of the astronauts unquestionably had a tremendous effect on all echelons of people involved in the program.

One technique deserves special mention; this is the technique of errors study and brain-storming sessions which grew out of these studies. Once errors were identified they were discussed with the employees who made the errors and they were invited to participate in resolution of the problems and the prevention of the errors occurring again.

Another technique was the seminars which were conducted with groups which contained people from all levels in the plant. This philosophy was based upon a belief that these people, be they engineers, or technicians, had to work together, so why not educate and train them together?

These techniques applied by Astronautics were fanned out to and used by the subcontractors and suppliers.

This point was emphasized by the AiResearch representative on the panel. It was interesting to note the close comparison of results that were obtained by Astronautics and by AiResearch in the one area in which

the statistics were presented. This is the area of decrease of errors after an error analysis had been conducted and discussed with the employees.

It was found that an approximate 40 to 50 percent decrease in manufacturing errors was obtained after the conduct of these programs.

The selection and retention of key people in positions, enjoying positions on checkout crews and launch crews appears to have been a very essential point in the motivation program.

Once again, the identity of people with the job and the use of special badges and decals played an important role.

One point made by our local Air Force Plant Representative, Colonel Richardson deserves special mention also; this is the requirement for consistent actions throughout the design, test and manufacturing processes.

For example, it does little good to induce an electronics technician to do quality work if he is aware of a failure report which has been submitted on his procedure or his equipment that takes weeks and possibly months to resolve in a corrective action to that procedure or to that equipment.

Our question period, though short, involved many stimulating questions for which we thank the audience.

I will summarize the answers to two of these.

Although Mercury was unique in many respects, it is the opinion of the panel, and I don't think it was rebutted by the audience, that many of these procedures can be applied in the future to bigger, larger programs.

And indeed, as brought out by our NASA representative, many of these procedures are now being applied by GD/A in the Centaur program.

Also, the application of these techniques to a program such as Mercury need not result in a degrading of the effort on other projects being conducted by the same company. Indeed, we feel that the improvement

in performance can catch on in these other projects and upgrade the work that is being conducted.

Finally, to those of you who might attempt to apply some of the Mercury techniques to other programs and other companies, you should expect reticence or resistance to the application of some of these techniques.

The techniques in Mercury were not conceived and instituted in one day, and believe me, they involved a strong selling job, in many cases.

As with everything else, there is a learning curve and what you are doing is fighting for a relationship between costs, schedule, and quality which turns out the best product possible.

We must remember two things: the first one is obvious, that people can only be pushed so far; but perhaps a more subtle point and one which may not be too evident, is in the matter of human motivation.

It is very difficult to find a yardstick and to measure your results.

I can only say that it is the opinion of the people on this panel and all the other people connected with the program that I know that motivation played a very large part in the success of the Mercury program.

MR. DEMPSEY:

Thanks, Bob.

The third panel in the morning dealt with Supplier and Vendor Controls and Relationships and Colonel Frank Brandeberry was the Chairman of that panel.

I will ask him to summarize that.

COLONEL BRANDBERRY:

On the importance of reliable suppliers, individual reliability of each procured component contributes equally with all others, including those manufactured by the prime toward the reliability of a complete booster mission.

Suppliers are a part of the team and we cannot succeed without them.

The importance of vendor selection is to obtain reliable suppliers at optimum cost and on schedule. The primary consideration must be that a vendor has the capability to provide a reliable product which will perform its intended mission or function.

A good vendor rating program is essential to provide objective evidence of demonstrated capabilities of a supplier. This data provides management control to assure vendor performance and to provide criteria for follow-on procurements.

Vendor seminars provide attention to the human factors position of the problem and allows for direct communications between the contractor and his vendors.

Purchase order control is essential to assure that you order exactly what you want and you order from a vendor whose capability to deliver a quality product has been evaluated and found acceptable.

Vendor corrective action is essential to preclude quality degradation, program impact, and excessive costs.

Associate contractor programs are equally important. Identical quality and reliability requirements should be contractually implemented for all associates to preclude interface anomalies and to assure major reliability of the integrated system.

Subcontractor programs are also equally important. A chain is no stronger than its weakest link. Similar controls and procedures should be imposed on all types of subcontractor performance to preclude performance discontinuities and faults.

We are vitally concerned that the contractors' QC system provides and maintains effective controls which will assure procurement of quality products at optimum cost and on schedule.

We are equally concerned that contractors' and vendors' top management recognize the importance of a vendor quality assurance program

and that it provides comprehensive direction and control to assure disciplined implementation.

As far as the question-and-answer period that followed, I think we had very good response. I am just sorry that the time allowed was so short, but I hope that we have stimulated some thought in those that attended our meeting so that further discussions can be had on the subjects presented.

MR. DEMPSEY:

Thank you, Frank.

In the afternoon there were again three sessions and in the general area of design or design controls.

How about Mr. Bailey summarizing the conclusions of that group?

MR. BAILEY:

Those of us down here on this end, of the afternoon sessions, were rather shortchanged on the time to prepare this summary, so you will have to bear with us.

In our session on design controls I think the first thing that was emphasized by Howard Newman was the advantage that Mercury enjoyed by starting with a launch vehicle that was pretty well along in its development cycle. He stressed the importance that was attached to maintaining this advantage by rigid control over changes; by rejecting all unnecessary ones, and by very careful study and tests of the really necessary ones.

He also pointed out the advantage of having a concurrent flight program and before use for flight check of problem areas before manned flight.

The next paper dealt with design review by Phil Culbertson, and he emphasized the extreme importance of successive design review, in depth, even down to the smallest engineering detail, and in particular he pointed out the importance of having the review team composed of people whose experience commands respect and whose stature in the organization forces their findings to be translated into corrective action.

Bob Kreisler discussed product review and he emphasized the usefulness and effectiveness of the tiger team approach in examining the actual hardware to insure that it did in fact conform to the design intent.

He pointed out that part of the benefit of this approach was in the findings of the team itself, but that there was also a benefit from the incentive that was given to the people doing the work to get the hardware right after the team looked at it.

He also emphasized the benefit of this tiger team approach in improving communication between designer and operators.

Bob Schaelchlin discussed the abort sensing and implementation system. This system was unique in that it was the one system that was designed specifically for project Mercury and at a somewhat later date than the systems in the vehicle and it did undergo perhaps more of the modern reliability and test programs and the flight test to demonstrate reliability.

It also underwent flight tests prior to use on Mercury and I think its most unique feature perhaps is the weapons system's use of redundancy to increase reliability at this subsystem level.

Major Gandy commented on the Air Force role in design control and mentioned the early recognition of the critical need for design surveillance and very rigid control which at the time it was instituted was not fully in effect throughout the missile industry.

He pointed out the recognition for the need of high engineering capability and the need for personal attention at the very high level in the companies.

He also commented on the effectiveness of the high level technical review boards that were set up starting prior to manned flight, about the time of MA-3.

Ernie Letsch commented on the Aerospace role, providing an independent review in some depth of all proposed changes, regardless of who proposed them, and the implementation of changes and the effect of changes on other systems, also including the optimum scheduling of

changes and he mentioned the check points that were set up at the factory role and the flight safety review at AMR.

The question and answer period was quite energetic. There were a large number of questions. I am not in a position to summarize them at this time, but I think everyone derived a great deal of benefit from the discussion period.

MR. DEMPSEY:

In the session on Manufacturing and Process Controls, Colonel Andresen, the plant representative at Astronautics, was Chairman. Formerly he was the Deputy Program Director for Atlas at BSD, so he probably knows as much about controlling Astronautics as anybody in the country.

COLONEL ANDRESEN:

At the session, in addition to the many topics that you have heard mentioned by the previous Chairmen, we touched upon such things as increased care and planning and the type of planning we are talking about here is the detailed planning that extends down through the whole fabrication process.

Then we touched upon the precision required in the setting of the tools and so on of that sort and the requirements for close care in cases of calibration, as well as talked about how the evolution of the requirements for cleanliness of parts was developed during the Mercury program and the new techniques that had to be employed, the new methods of inspection, and the facilities that were required to achieve these objectives were developed.

Then we talked about the stringent control over parts and the type of reviews that we would go into prior to the time that we would decide that we could rework a part and then it was stressed that one of the things that was found to be advantageous in the program was that a quality control engineer, which could be identified with a particular missile, was established at the conception of the fabrication process and stayed with the particular missile down through the time that it went down to the Cape for tests.

This was extremely beneficial in that it gave continuity to the quality control aspect of the program.

Material review was touched upon and the difference in the treatment of material and review which centered largely about the composition of the Review Board and essentially what happened was the Board composition was moved up to a higher echelon within the organization.

The requirement for production evaluation testing was explored and then also the search for critical weakness and of course the search for critical weakness was very revealing and very beneficial to the program and it is the type of thing that in future programs will be beneficial also.

Then the critical components selection criteria engendered quite a bit of discussion as to how this was carried out and was this helpful and what was the criteria for the selective and generally the criteria was developed.

Instead of using the whole spectrum of the range of acceptability, you took a point in the center of the range and made your selection in accordance with that.

Then importance of having the missile completely finished so that there were no open items prior to the start of tests was talked about. Many of the new controls that were developed in the Mercury program were then transferred to other missile productions, and of course, this has been extremely beneficial and has enhanced the general quality of all products going out of the plant. That too was stressed.

The question of problems was touched upon and the method of resolution. This ties back into the earlier discussions of management, communication, organization, and so forth, and the unique thing about the treatment of problems was it wasn't really so unique. It is probably a disciplinary matter; that was that the problems were transmitted up to a point in the organization, whether it be Air Force, NASA, or contractor, where you could insure that the decision was acted upon in a timely manner and with the authority that was required to execute whatever findings came out of the decision.

Configuration was explored. Of course, the configuration perhaps has achieved its highest degree of perfection in the Mercury Program and I

hope that it is carried on into other programs. However, it was an item that was brought out throughout the discussion as being essential to the accomplishment of a good product.

Then a new topic, to me, was developed from the floor, and this was the subject of documentation requirements between manufacturers and what we are talking about here is that one manufacturer, when buying from another, is vague in what his documentation requirements are. Then, if he gets into a situation where a vendor is supplying to a customer, he doesn't know whether he has the right documentation. Is this what is required, and how do I accomplish this requirement for documentation?

There appears to be no standard situation between manufacturers, and of course, the key point of this one is, I think, that it is a dual problem, common to both industry and Air Force.

On the Air Force side of the house it was brought out that we do have a committee working on this thing. That was introduced by General Schriever, to come up with some common form of documentation so we can talk in common language of documentation between manufacturers.

However, I think there is a companion action that may be taken up with the industry association to do a little bit to help the problem too.

This was quite an interesting discussion.

Then perhaps the key question that came up was that didn't the upgrading of the Mercury degrade the quality of the other missiles and the pros and cons of this particular point were banded about and in conclusion I think the group generally felt that rather than degrade the quality of the other missiles that those going to the weapons systems or perhaps other programs, it had a beneficial, rather than a degrading influence, because there was a trading of ideas back and forth.

For example, the two configuration boards, the one for the reference system and the one for the Mercury Program exchanged information about changes and this was beneficial in that it gave the independent review, as was mentioned in some of the earlier discussions, to a

particular change and it ended up in perhaps having a better weapons system and also a better Mercury.

The final summation, that I think that one could conclude from our group was the fact that the quality produces better schedules. So, the little triangle isn't actually distorted if you get the quality into the program. This, in substance, was the summary of our discussion.

MR. DEMPSEY:

Thank you very much, Andy.

Testing was a fascinating subject and covered by Merritt Preston in his group.

Merritt.

MR. PRESTON:

I plead with Bailey over here that we had a short time to prepare this and we discussed to the very end. We were really going hot and heavy when they came in waving their arms to shut us off.

I think one of the primary things that was brought out in the discussion of testing was that there has to be a very studious review of how much testing should be conducted on flight hardware. There was quite a discussion about over testing and under testing and I would get the impression that the consensus that was on Mercury at least, that the fear of over testing is probably too predominant in most programs; that you have to give your equipment a chance to fail by testing it and therefore we should do considerable testing on the flight equipment.

We had discussions of the testing done at the Qualification and Environmental testing. We also had discussions of the supplier and receiving inspection testing of the actual flight hardware, the factory composite tests run here at Convair -- or, GDA, beg your pardon.

Where they have a composite team really, not only a composite team, but a composite team of the Air Force, GDA, and Aerospace to conduct a test.

And this brought back the favorite subject of teamwork, which I think is one of the fundamental things throughout Mercury that is important, because early in the program we were able to define what the jobs were; then allow the people to do the jobs without too much interference.

I think that the good relationships between NASA and the Air Force stem from the fact that NASA and the Air Force have a mutual respect for each other and allowed each other to perform its own tasks.

Now, some detail things that came up in the testing area was that too often the odd data points that we run into are adduced as bad data when in truth and in fact they are the good data and the important data that you look at and find out what caused that bad data or that peculiar data, and doing something about correcting it because it is usually a sign of some trouble to occur in the future.

It was also pointed out that the need for documentation of testing, first of all so that you had adequate planning; then the planning would guarantee that you, through this documentation, knew it would perform a good test, and secondly, if you have good documentation and you have a malfunction or a failure, you have good records so you can go back and analyze what happened to determine a corrective action.

It is also indicated that it was the necessity for stopping whenever you had trouble and analyzing the problems and taking this corrective action, rather than charging on and hoping that it won't reoccur.

In conjunction with the test program there was a detailed failure analysis program so that every time there was an anomaly in the testing phase and any failures a detailed analysis was conducted in every case and a conclusion was reached before any flights were made.

And we went even further in Mercury in that we were conducting searches for critical weaknesses and over stressing through testing equipment, so that we could find out just how much of a margin of safety we had.

Now, this is a rather novel idea and I think a very valuable one, because it gives an idea of how far away from the breaking point you are.

Another thing that came out of Mercury was a unified test program. It wasn't initiated in the beginning but it was toward the end where they assimilated total testing that was being conducted to get an overall picture of the testing so that they could make more efficient use of the test time, and therefore, thereby save time on the equipment but still get adequate testing.

Finally, I guess one of the biggest and liveliest discussions was about how to apply this experience to other programs.

Automatically, I think GDA will extend this knowledge to new programs. I also think that naturally the Air Force, with their teams that were participating well; now, sir, of course, in its participating will.

The problem really comes down to how do the other people in the space business assimilate this information and this, of course, was the purpose of the conference.

I think there is one thing that must be stressed and it is the motivation concept again. When you find troubles in testing it means troubles to you to find out what went wrong. It means that you have to create an extra effort to do something about it, to fix it, and it is particularly annoying when it occurs just before you get ready to fire the bird on minus-one day.

The motivation in Mercury was -- of course, there was a man there and you could not afford to allow him to take any extra risk, so you do something about it. I think in these other programs you have to assimilate yourself so that you will be willing to correct everything that you find and have no tendency to brush things off.

The discussion lasted for an hour and it was a very lively one.

Thank you.

MR. DEMPSEY:

Thank you very much, Merritt.

Due to the remarkable efficiency of our panel chairmen in summarizing, we are comfortably well off with respect to the time, so we do have

a few minutes that we might use for further cross-feed if there are any questions or additional discussion which anybody on the floor would like to make.

(No response.)

If not, Colonel Hoffman has a word he would like to say for just a moment.

COLONEL HOFFMAN:

I would like to take this opportunity to thank Mr. Dempsey for hosting this particular meeting. In my personal opinion it has been very effective and I hope it will provide a sort of pattern we can follow in other programs.

MR. DEMPSEY:

I would like to remind everybody that we will send a copy of the proceedings, if that is the proper word, to those people who fill out an address sheet, which the secretary just outside the door has.

Insofar as anything you heard today that involved the Astronautics Organization, I would like to invite anybody who is interested in hearing more about it or learning more about it to come back and visit us at any time in the future, because we think any way we can spread the information that we have learned we would be glad to do it.

We are also interested in whether or not the purpose of transmitting experience, you might say from a program in the beginning of our space age here, has been accomplished to any extent today and if any of you have any comments about the program activities, if you would just pass that on to anybody wearing a host badge out around the pool, we would be pleased to have that information.

And now we adjourn somewhat ahead of schedule for cocktails around the pool for those who are interested.

Thank you all for coming.

(Whereupon, at 4:45 o'clock, p.m., the workshop was adjourned.)